POLITECNICO DI TORINO

Master of Science in Civil Engineering Thesis

Application of standards in the MEP modelling and data management throughout BIM methodology

Case Study: Piattaforma Logistica di Trieste

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A mis viejos, quienes gracias a su esfuerzo

hicieron posible mi sueño de estudiar en el exterior.

A mis hermanas, por el apoyo incondicional de siempre,

en especial a Cele, por las correcciones en la redacción.

A todas las amistades que hacen más llevadero este viaje,

tanto las que conocí en Torino como las que me brindaron su apoyo a la distancia.

Abstract

English

The following thesis deals with BIM methodology implementation in Trieste's Logistics Platform enlargement project. The thesis is focused on the modelling of the Mechanical, Electrical and Plumbing equipment (from now on called MEP). The thesis development was contemporary to the construction activities, so the work is based on preliminary design documents. The main goal of the thesis is to elaborate a model that follows as accurate as possible international standards in support of collaboration and interoperability.

The thesis is divided into chapters, settled in chronological order as they were developed. The first chapter includes some BIM methodology background, especially focused on MEP, and an introduction of the study case. A second chapter explains in detail the information production process, including tools implemented and standards followed. A third chapter is focused on the delivery phase of the information, where it is explained how information has been exchanged between the different teams involved in the design. The next chapter mentions some applications the model could improve by implementing BIM, what standard calls information management. The first part discusses the inclusion of a fourth dimension into the model using Synchro software. The second part focuses on the facility management activity. The idea is to describe from a critic's point of view what has the author considered the best practices for achieving the set goals. In addition, the thesis is also focused on interoperability problems that may occur while working with BIM projects.

Italian

La seguente tesi tratta sulla implementazione della metodologia BIM nel progetto di ampliazione della Piattaforma Logistica di Trieste. La tesi è focalizzata nella modellazione degli impianti meccanici, elettrici e di piombatura (da ora in poi chiamata MEP). Lo svolgimento della tesi è stato contemporaneo alle attività costruttive, quindi il lavoro si basa su disegni in fase preliminare. L'obiettivo principale della tesi è quello di elaborare un modello che segua il più fedelmente possibile le norme internazionali a beneficio della collaborazione ed interoperabilità.

La tesi è divisa in capitoli, ordinati di maniera cronologica a come sono stati sviluppati. Il primo capitolo include materiale teorico sulla metodologia BIM, soprattutto focalizzata nella parte MEP, e una introduzione del caso studio. Un secondo capitolo spiega il passo dopo passo per il processo di produzione dell'informazione, includendo gli strumenti implementati e le norme rispettate. Un terzo capitolo è focalizzato nella fase di consegna della informazione, dove si spiega com'è stata scambiata l'informazione tra i diversi team coinvolti nella progettazione. I seguenti capitoli fanno menzione su alcuni possibili usi del modello affinché la implementazione del BIM sia approfittato. La prima parte tratta la inclusione di una quarta dimensione nel modello grazie all'uso del software Synchro. La seconda parte si focalizza nell'uso del modello per il facility management. L'idea è quella di descrivere da un punto di vista critico quali sono state le pratiche che l'autore ha considerato come le migliori per raggiungere l'obiettivo. Inoltre, si fa particolare attenzione in problemi di interoperabilità che possono capitare nella elaborazione di progetti BIM.

1. Introduction

Modern building engineers and architects have heard about BIM at least once over the course of their career. Over the years its popularity increased so much, that some countries adopt it as a requirement for public works. This strongly point which way professionals and companies in the Architectural, Engineering and Construction industry must follow if they want to remain competitive.

BIM acronym, which stands for "*Building Information Modelling*", has been first introduced about the 90's in a paper written by G.A. van Nederveen and F. P. Tolman. However, it has not become popular until the principal software developers for AEC industry included it into their terminology as a common name for the digital representation of the building process. Until then the information consisted on 2D geometry or at least 3D simple models, from this moment it became possible to add information to the different elements by using attributes.

At that time the application of BIM was reduced, but as technology evolved, new BIM based software were introduced to the market and BIM potentiality has drastically increased. Nowadays this methodology can be used for different purposes, from cost estimation to maintenance scheduling. The following table gives an idea of the activity spectrum of what can be done by using BIM methodology.

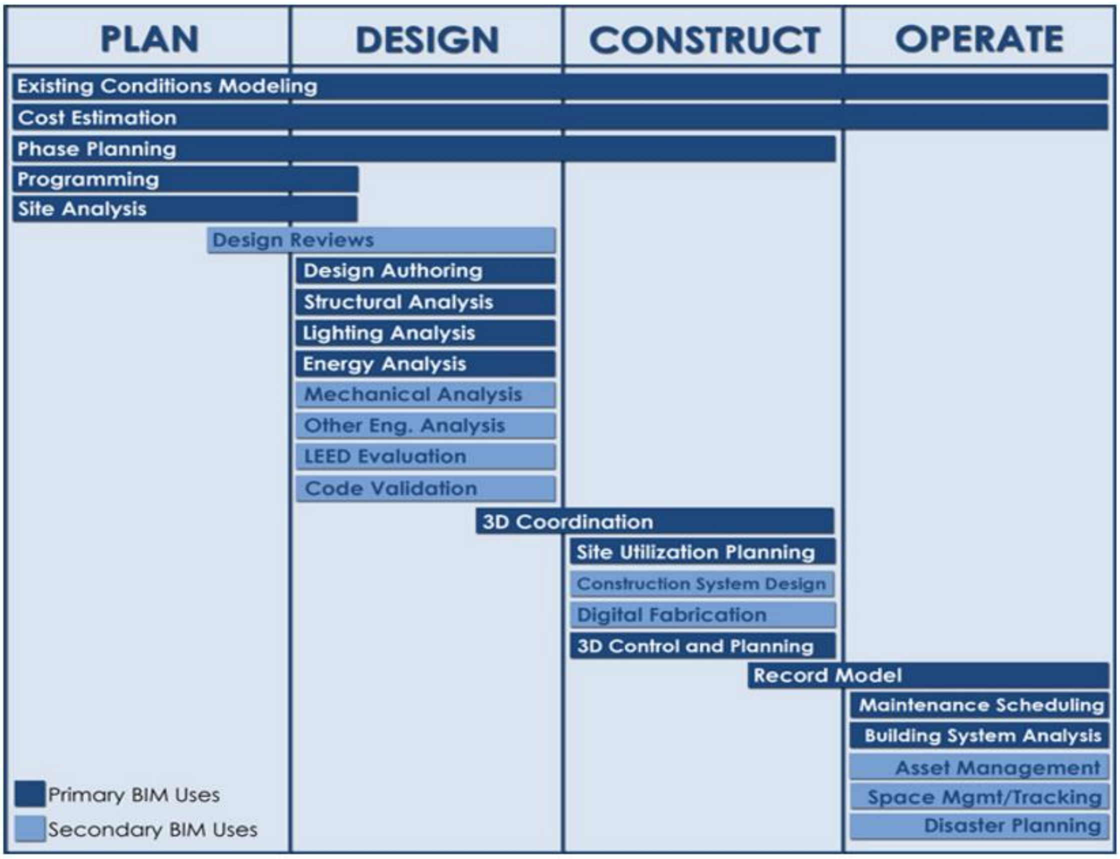


Figure 1 - BIM uses (Computer Integrated Construction Research Group, 2010)

First of all, it is important to highlight the difference between the two concepts that are called the same way but mean two different things. Some people refer to BIM as the

Building Information Model, which is the result of the implementation of the process previously mentioned. This model is just the geometric representation, within the spatial and contextual relationships, the constraints and building quantities and properties. The term to which this thesis will refer as BIM is "*Building Information Modelling"*, the methodology.

Creating a Building Information Model means to construct something digitally. This means that for BIM-based projects the construction is made twice, what usually is reflected into precious time and resources for creating a model. These models, however, increase the understanding of a project as well as improves communication between design and construction team. This way, many risks related to the construction phase are avoided, increasing the profitability of the project (NBS, 2016).

However, this is not the only benefit that can be taken from the use of BIM methodology: The model created during the design and construction phases, once the construction is finished, should be updated in order to get the as-built model. The *as-built model* consists on a group of objects, that will represent the assets in the building. This model can be updated each time small works take place, such as repairs or replacements. By doing this, it is obtained an *as-is model*. The objective of having an updated model is to improve the efficiency in operational phase activities.

The important concept to highlight is that BIM is not also helpful in the design and construction phases, but also in the operational and demolition ones. Because of this, it is said that BIM data can be used to manage the entire building life-cycle.

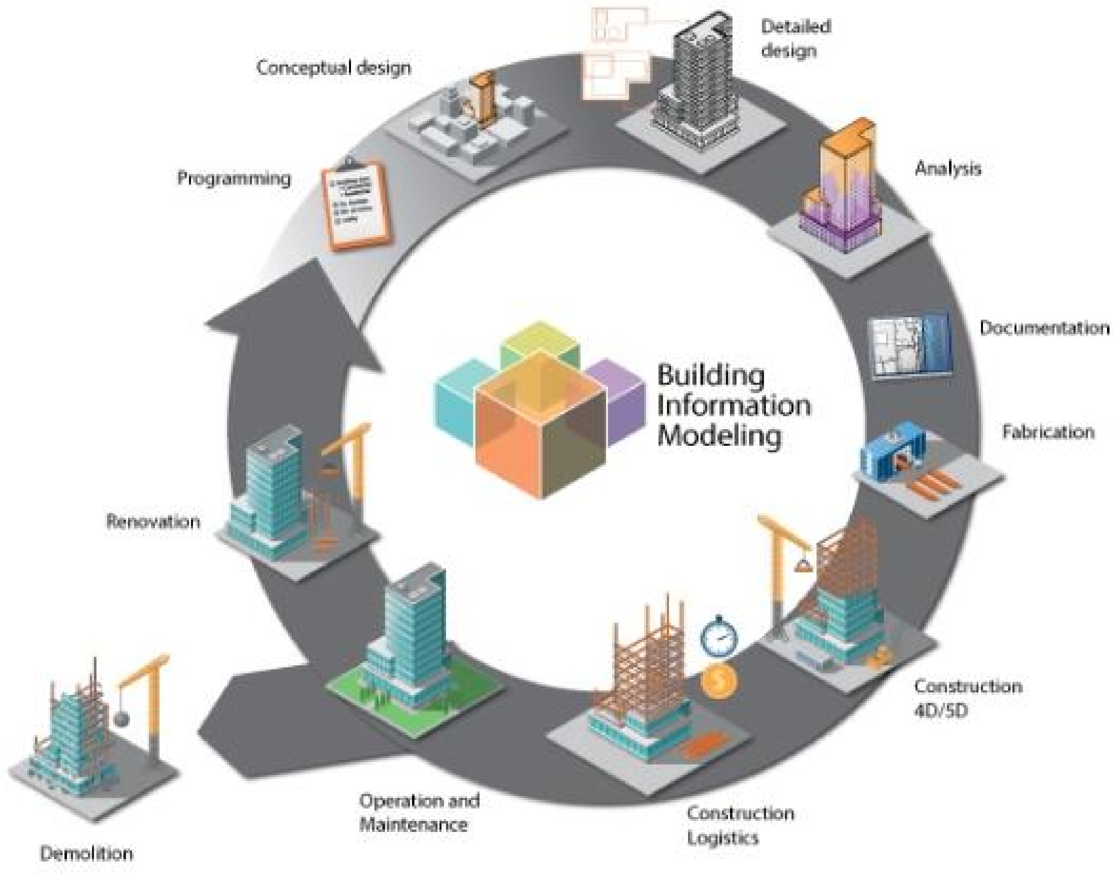


Figure 2 - BIM influence in the project lifecycle (Cambodian Constructors Association, 2016).

1.1. Interoperability

In the project delivering process, many actors are involved. These actors are usually grouped by parties, which are at the same time assembled into teams when they have to perform a specific task. Parties exchange information in the appointments. The appointed party is who provides the information to the appointing party. This information must follow some requirements in order to be exchanged. The information is formed by containers and the set of containers form the information model. These information containers are practically all the files generated by the project team, which can have several extensions depending on its nature.

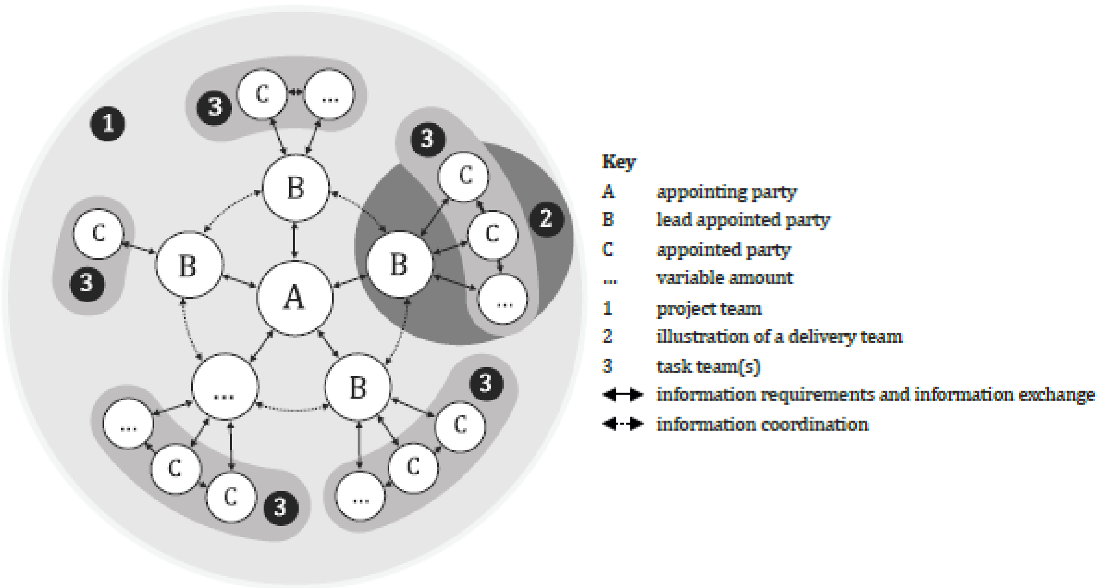


Figure 3 - ISO 19650 interfaces between parties.

It is important to mention that there is not only one unique software encompassing all the activity spectrum. A software is a tool created for a particular purpose. During the information creation process, designers may need different software of different firms, which use different formats and languages. This is where the term interoperability comes up.

It is possible to see a project as the biblical narrative of the Tower of Babel. The story takes place in a time when all humans spoke the same language. Men decided to create a tower that could reach the sky. Nevertheless, when Yahveh (God) saw the tower he felt threatened, so he decided to create different languages. The multiple languages made people get confused and consequently the tower could not be finished. It is possible to compare the people involved on its construction with the different software, as well as the tower of babel with the aim of the project. The lesson from this story is that in order to reach an objective, all actors must unify the way information is exchanged.

The idea of creating standards is born following the same principle. Actors that follow the same standards speak the same language. Unfortunately, there are lots of different standards even in the same country, like the case of USA. They were created in order to fulfil different requirements. The use of British standards for managing information became very popular on BIM environment, so nowadays the creation of an international standard based on those standards is in progress.

The term that defines how well is information exchanged between two different software, is called interoperability. Usually during the process of importing and exporting files from a software to another, some data are lost. These data can be graphical or even alphanumerical. The best is having a model interchange without distortions. The less information is lost, the better interoperability between two different software is.

OpenBIM

OpenBIM is a universal approach to the collaborative design, realization and operation of buildings based on open standards and workflow (BuildingSMART, 2016). The use of openBIM results in many advantages like the creation of a common language for widely referenced processes and the support of a transparent open workflow that allows project members to participate regardless the software tools employed. It is an initiative created by BuildingSMART in collaboration with the principal firms on the BIM software Industry.

IFC Standard

IFC standard is only one among five types of open standards in the BuildingSMART portfolio. It has been translated into an ISO standard, the ISO 16739. The standard refers to information and data transporting. It basically promotes the use of IFC open format for sharing all the building information.

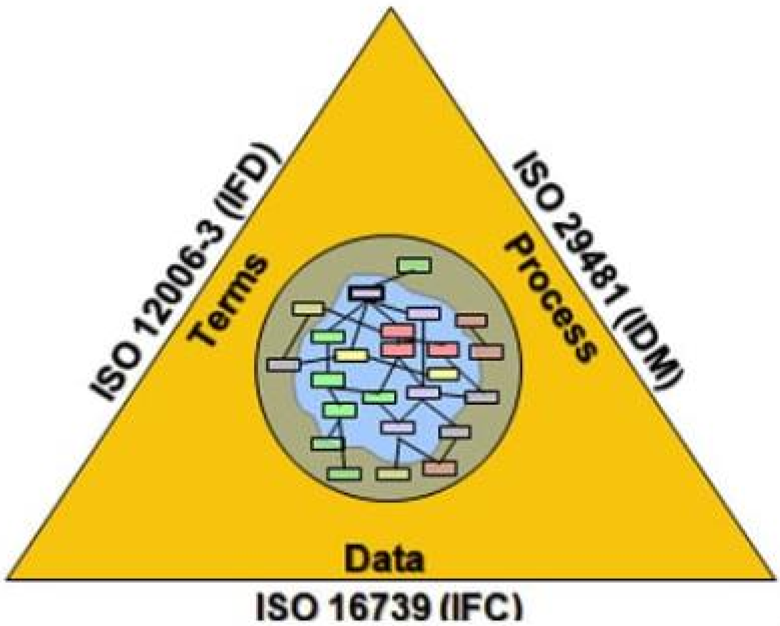


Figure 4 - International standards oriented to interoperability improvement. (BibLus-net, 2017)

1.2. MEP engineering

The MEP acronym stands for mechanical, electrical and plumbing engineering. MEP engineers are responsible for making buildings interiors suitable for people.

These engineers must deal with different challenges like spatial coordination, effective functioning of parts in a system or installation, testing and maintenance procedure (DesigningBuildings, 2018).

Mechanical systems include generally all systems related to Heating, Ventilation and Air Conditioning (HVAC) systems. Nevertheless, some other systems can also be included like lifts, escalators, or other transporting system. Their objective is to maintain a good quality on air, regulating temperature and humidity. Mechanical systems must avoid being oversized since this brings negative consequences like temperature fluctuation, fast degradation and poor humidity control (Tobias, 2018).

Not only power supply but also other systems conform the electrical system. Among them it can be mentioned telecommunications, control, security, detection and lightning systems.

Plumbing systems are associated with fluid movement. They can be used for many different purposes, like water supply, recovery and treatment systems, water drainage, waste removal, among others.

MEP engineers help in the design stage by providing information about the spaces to be occupied by the equipment, since location conflicts are very common. The use of BIM is strongly recommended during these phases since a good collaboration with the other teams will result in time reducing and consequently efficiency improvement. Another added value for MEP design is the use of models for energy, lightning or mechanical analysis, which allows to optimize the system design by the use of specialized software, using the less resources possible.

MEP models may also be useful for operational phases, being conserved as reference for maintenance activities.

Figure 5 – Example of MEP model in Revit (Cadeosys Training).

1.3. Reference standards

British Standards

The British standard PAS 1992 is one of the most famous standards related to BIM methodology around the world. This code of practice was released by the British Standard Institution (BSI) and sponsored by the Centre for the Protection of National Infrastructure (CPNI). It was the first to introduce the BIM Level of maturity concept. On this standard, a very popular diagram for BIM users is introduced, the well-known “wedge diagram”.

From April 2016, the UK Government requires fully collaborative 3D BIM for all centrally-procured public projects, representing a minimum of level 2 BIM. Since 2019 this standard was the one that expressed the procedure required for getting to that level. Henceforth, the international standard replaces it within the PAS 1192.

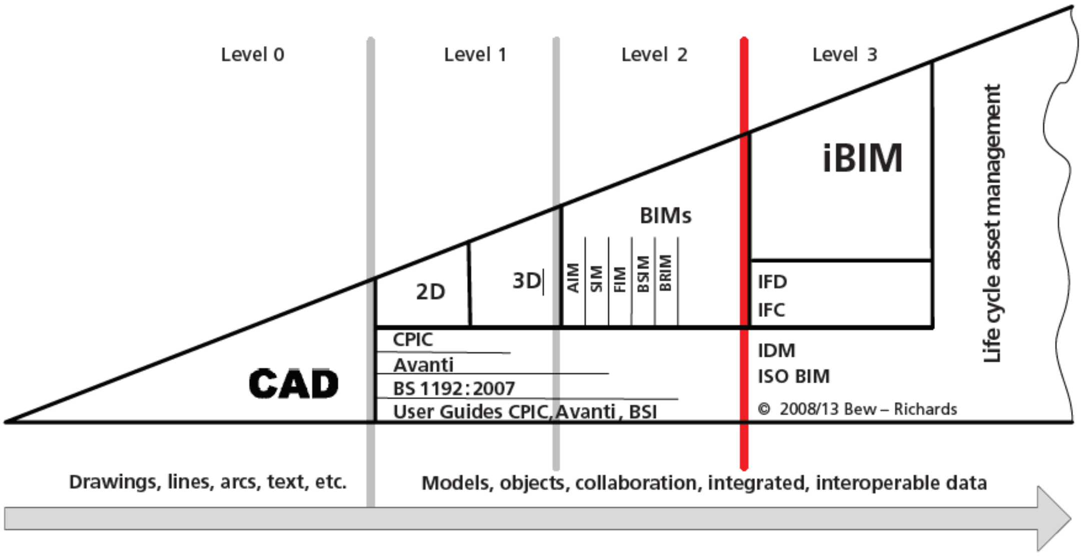


Figure 6 - PAS 1192-2:2013 BIM maturity model.

BS 1992 is the British standard that offers an important guide for professionals involved in the information construction process during the design, construction, operation and decommissioning of the projects (DesigningBuildigs.co.uk). It covers different topics like the naming conventions of files and layers or the information management through a Common Data Environment.

Italian Standards

Regarding to the Italian context, on 1/12/2017 the Infrastructure and Transport Ministry (Ministero delle infrastrutture e del transporto) published Decree number 560, known as “BIM Decree”, which defines the methods and timing for the progressive introduction by contracting authorities, granting administrators and economic operators of the mandatory methods and specific electronic tools, such as those for building and infrastructure modelling during all the works lifecycle.

Furthermore, the Italian Organization for Standardization (UNI) in the last years created a standard based on the last-named decree, divided into 10 parts, that is still in progress. Since July 2019 the parts published are the 1, 4, 5, 6 and 7. Satisfy the need to define a reference regulatory framework that favors the spread of digitized collaborative work environments, where product and process information is generated, managed and shared, according to procedures and reference standards, with the aim of improving communication, product quality, production sustainability and user satisfaction.

It must be also remarked that the discipline code that rules the relationship between contracting authorities and contractors in the case study of this thesis is the legislative decree N° 50, also called “Codice d’appalto”. This code corresponds to all concession from public authorities for more than one million euros, as well as contracts for building works related to hospitals, sport or recreational centres, educational buildings and buildings oriented to the public administration functions. Other works are also included, but in general it refers to all public works. The last version of this code was released on 16/4/2016, until July 2019.

International Standards

ISO 19650 is the international standard regarding information management. Its edition is still in progress, but there have been already published the first two parts on the first quarter of 2019. The standard encompasses the whole life cycle of a built asset, from its creation to its demolition or replacement. It contains all the principles and high-level requirements for getting a BIM Level 2 of maturity.

Its publication replaces the British Standards BS 1192:2007 + A2:2016 and PAS 1192-2:2013. It was created in order to have an internationally accepted approach for information management. The objective is to increase the value to be derived on international projects or projects that involve teams from several nations.

The standard represents the information management as a sequence of maturity stages, from 1 to 3. It has some differences respect the wedge diagram- One of them is the absence of the Level 0 BIM, and the inclusion of a business layer.

BIM Stage 1

It includes all projects where users generate mono-discipline models and where no significant model-based interchanges take place. The data exchange is uni-directional. If the models are not exchanged between project participants the practice implemented is known as “Lonely BIM”, term adopted as the opposite of “Social BIM”. The conventions may accept national standards but does not respect international standards about information management.

BIM Stage 2

Participants collaborate actively by introducing its disciplinary models into a federated multi-discipline model. The federated model does not lose its identity or integrity. The model exchange is two-way. Information about construction sequencing and costs may be included. Stage 2 maturity is also identified as “BIM according to the ISO 19650 series”.

BIM Stage 3

Full-integrated models are created, shared and maintained collaboratively across all the project lifecycle. This can be done thanks to the use of model server technologies in which models are combined no matter what software BIM tool was used for modelling it. The result is an integrated model that merges all individual integrated models' properties into a single database. In this stage, most of the project team is collaborating across all the project lifecycle.

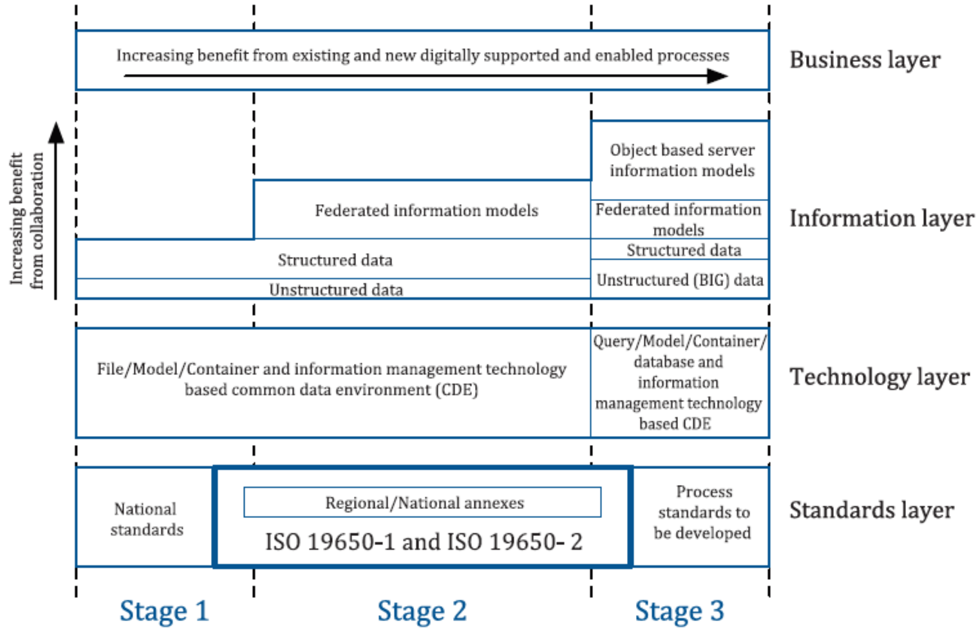


Figure 7 - ISO 19650 stages of maturity of analogue and digital information management.

1.4. Common Data Environment (CDE)

The British Standard BS 1192-2007 considers that a Common Data Environment (from now on CDE) approach should be adopted in order to allow information to be shared between all members of the project team. A CDE is basically an online place for collecting, managing and sharing information among a team working on a project. It also appears in the Italian standard UNI 11337-1 but with its acronym in Italian is ACDat. It is defined as "an environment of organized collection and sharing of data related to models and digital documents, referring to a single work or to a single complex of works".

The international standard ISO 19650 declares that each information container should be in one of three states: Work in progress (WIP), shared or published. The CDE is the place where information changes from one status to another. Firstly, WIP information changes into shared status when the task team manager approves the information, checking that the model is suitable and follows the standards. The following status change from shared to published is made by the employer, who authorizes all the information that follows the client's requirements. The standard recommends the existence of an archive state where all the information container transactions are shown. The archive is also used for future reference and use.

The use of a Common Data Environment facilitates collaboration between team members and helps to avoid duplications and mistakes. Studies have determined that coordination inefficiency increment costs between 20 and 25% (Mills, 2015). For this reason, the use of CDE is becoming increasingly popular.

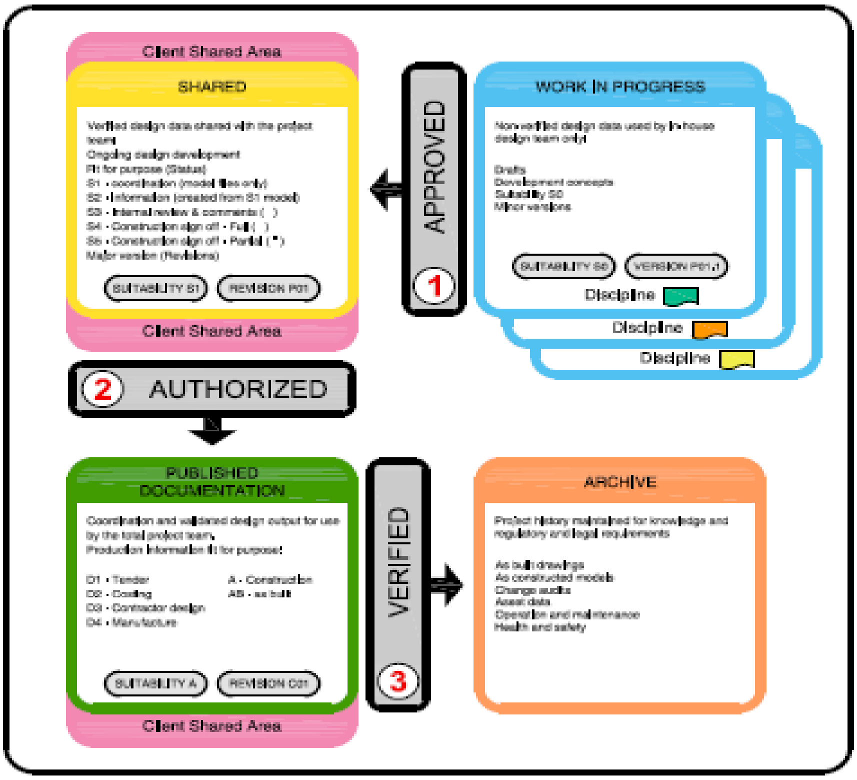


Figure 8 - PAS 1992-3 Common Data Environment information stages.

ISO 19650 standard makes a distinction between information management and information production and delivery. They are part of two different phases, that are distinguished as delivery phase and an operational phase. It is recommended to just transfer relevant information between these phases.

Project Information Model (PIM)

PIM is the information model developed during the design and construction phase of a project. The model must follow the Employer's Information Requirements. The project manager is responsible for developing the Master Information Delivery Plan (MIDP) and through this plan rule the way PIM will be developed. The MIDP indicates when, how and by whom the project information will be prepared, dividing the whole project information into tasks that will define the different teams and responsibilities. PIM will set the basis for the Asset Information Model.

Asset Information Model (AIM)

AIM is a term used to describe the model that contains all the necessary information for asset management. This model is managed within a CDE, and it can suffer many changes during the operational phase, due to maintenance work, repairs, replacements, performance evaluations, among others. In order to operate these models efficiently, some requirements must be settled up by implementing an asset management strategy.

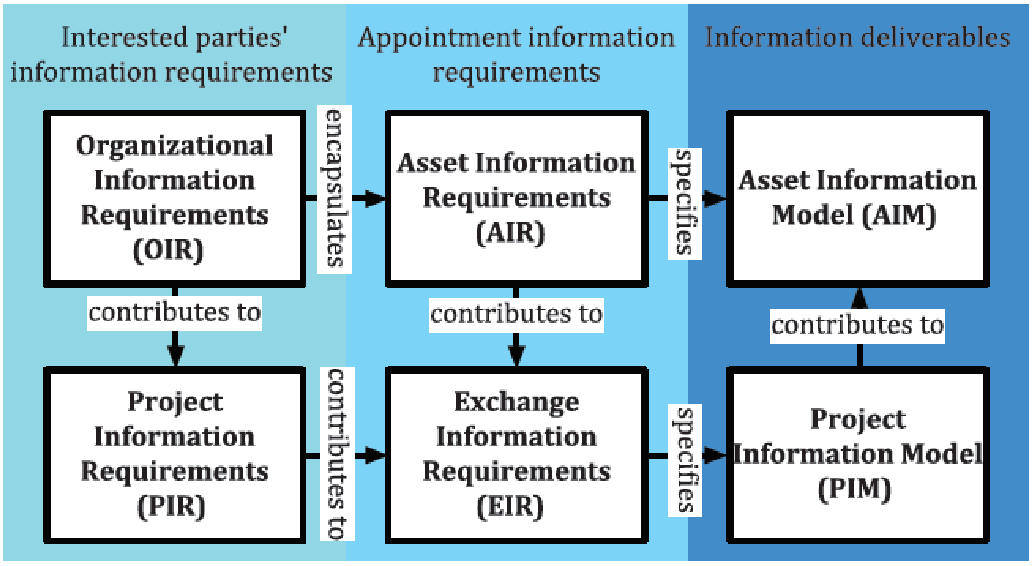


Figure 9 - ISO 19650, types of models and requirements.

1.5. BIM Dimensions

Three dimensions are generally enough for geometric purposes; however, BIM methodology allows designers to introduce new descriptive modalities that represent non-geometrical information.

3D BIM consists on modelling objects, either with graphical and no graphical information, and sharing this information in a Common Data Environment. A 3D model must meet standards requirements (also known as code checking) and it must not present geometric conflicts (analysis known as clash detection). These two activities take part in the "model checking" activity.

4D BIM includes the fourth dimension, consisting in the "time" element. The information is included in the scheduling data form. The new parameter added to the objects allows the development of more sophisticated activities, like a sequential visualization of the construction, the clash detection on time, warnings about potential threats.

5D BIM adds a new element to a project: the cost. This introduction allows to estimate the overall costing associated with it, giving the possibility of doing feasibility studies or making decisions according to the study of money outcomes and incomes.

6D BIM gives modellers the possibility of introducing sustainability and energy analysis into their model.

Finally, a **7D BIM** model allows to manage the life-cycle of a project and its services. It gives logistic control of the building maintenance, optimizing processes like inspections, repairs or replacements.

Figure 10 - BIM Dimensions (BibLus-Net, 2018).

1.6. Study Case

As introduced in the abstract of this thesis, the following chapters will cover some fundamental concepts about BIM methodology applied to a study case of an infrastructure located in the seashore of Trieste, the capital of the Italian region known as Friuli-Venezia Giulia. The infrastructure was projected in the zone limited by the terminal multipurpose known as “Scalo Legnami”, on the North, and the steel plant “Ferriera di Servola”, on the South.

Since the place was mentioned as a polluted place of national concern, in 2003, the seaport authorities have been looking for a solution for the environmental problems. It was not until 2004 that the “Comitato Interministeriale per la Programmazione Economica” (CIPE) approved the project called “Piattaforma Logistica Trieste” (PLT). The whole intervention was divided into two parts, while the case study represents the first one.

Figure 11 - Site presentation of the study case (General Report).

The following activities were done in this first intervention:

- Ground remediation of the seabed.
- Deviation and canalisation of an existing torrent called “Baiamonti”.
- Construction of an impermeable nearshore confined disposal, consisting on diaphragms made with CSM technique in the ground surroundings and groups of king piles forming a row in the sea adjacency connected to existing waterproofed caissons.
- Groundwater remediation, by collecting it with a draining trench, all around the confinent disposal area and then being carried by pipes to a treatment facility, located in the southern area.
- Platform with a Roll on-Roll off terminal where trains and vehicles will surpass.
- Ground regulation to quote +2.5 above sea level followed by concrete paving.

The company was looking for someone to model the equipment, since the rest of the models were being developed by other professionals from the company.

The reports mention some typical systems, like rainwater drainage and treatment, where water is captured from drains placed at 20 meters one from each other. Water collected from the platform is firstly derived from PVC pipes to a water channel placed under and around the platform, while water collected from the terrain is collected through concrete pipes. Both concrete pipes and water channel finish in one of the two treatment plants. These plants are placed under the terrain level. The total basin was divided in two: South and North, each plant is responsible for treating the water of its correspondent basin.

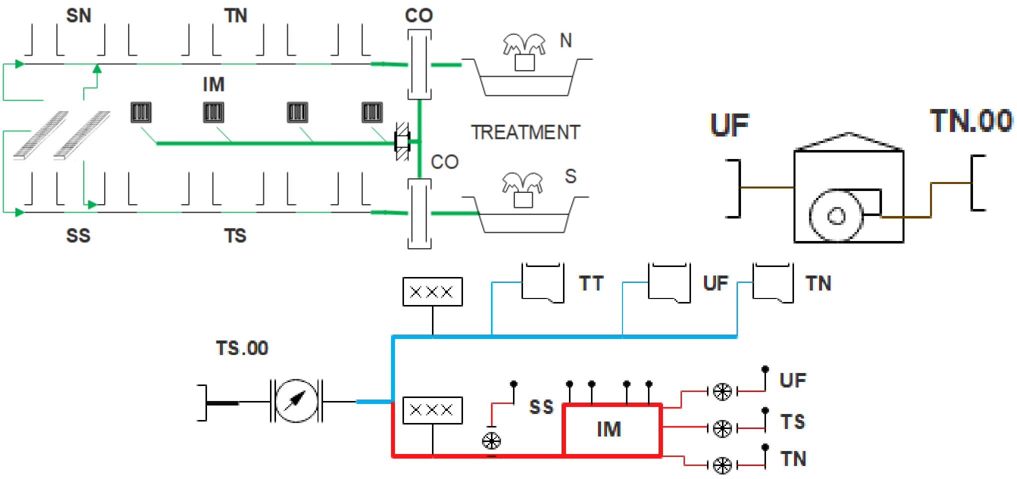


Figure 12 - Sanitary systems schema, on top, water supply on bottom.

The cold domestic water and firefighting systems have the typical building schema: water is provided from the street connection, and after passing the flow meter, the systems are divided. From that division, water is conducted through HDPE pipes to the different terminals: water tanks for the domestic water, and fire hydrants for fire suppression. Pressure provided is enough to dispense with pumping systems.

One of the piping systems is bound to the beach nourishment. This activity consists on putting all the material derived from the technical dredging into the confined disposal. The idea is to fill this volume with sediments until quote +0.50. This system is designed for dredging 2500 cubic meters of material per day. The material arrives to the platform surroundings by boat, so mechanical equipment provided with buckets relocate the material from boats to the disposal through an opening in the platform. This opening drives to a pit where a dredging pump is placed. This pump is responsible for divide the total of dredged sediments into 40m x 40m zones under the platform, by flowing them through HDPE pipes. If pipes are installed along East-West direction, they are called “transfer pipes”, else “deriving pipes”. A micro-impulse monitoring system that is constantly measuring the top of the sediment layer allows to distribute uniformly the sediments.

Another piping system has the function of collecting 300 cm/day of contaminated groundwater though draining trenches placed around the platform outside the impermeable confined disposal. It must avoid contact between groundwater and sea water. Once water is caught and stocked into pumping rooms, centrifuge pumps provide enough pressure to ensure that water arrives to a groundwater treatment plant placed in the South border terrain. This groundwater treatment plant is responsible for separating mud from the water through sedimentation and filtering processes. The mud is then treated by pressure filtering and stocked. The stocked mud must then be derived to a special deposit for contaminated material. The water, on the contrary, after the treatment process and consequent quality verification is thrown back to the sea.

Another piping system is necessary for treating the water retained into the confined disposal. 2500 centimetres of dredging material per day thrown into the disposal results on an increment of the sea level. For this reason, it is planned to construct a tank inside the disposal's perimeter whose function is to maintain the desired level. The tank is provided with an adjustable dump that allows the entry of the excessive water. It is possible to set the quote of entry from +0,50 to -0,50 meters above sea level. Inside this tank a centrifugal pump is hosted. This pump is responsible for driving the water in the tank to a specific treatment plant, placed next to the groundwater treatment plant. The decision of having both treatment plants together responds to the fact that when the confined disposal is almost filled with sediments (at least 80%), the water collected in the disposal will contain an important amount of colloidal sediments. Due to this, a deviation to the physical and chemical treatment device on the groundwater treatment plant is made. As can be seen, the objective of this system is not only to adjust the water level but also to improve water quality before throwing it back to the sea.

The last equipment the author decided to model consists on the air treatment system. The objective of this system is to avoid odour issues. The air volume inside the between the platform ceiling and the disposal is approximately 130,000 cubic meters. An air treatment system with a potential of 10,000 cm/hour is planned, so that two full changes of air inside this space are done each day. The air treatment system consists on an electrical aspirator that takes air and makes it flow through circular ducts until is exhaled into a biofilter, which is the responsible for removing smells by making air flow through its cortex beds.

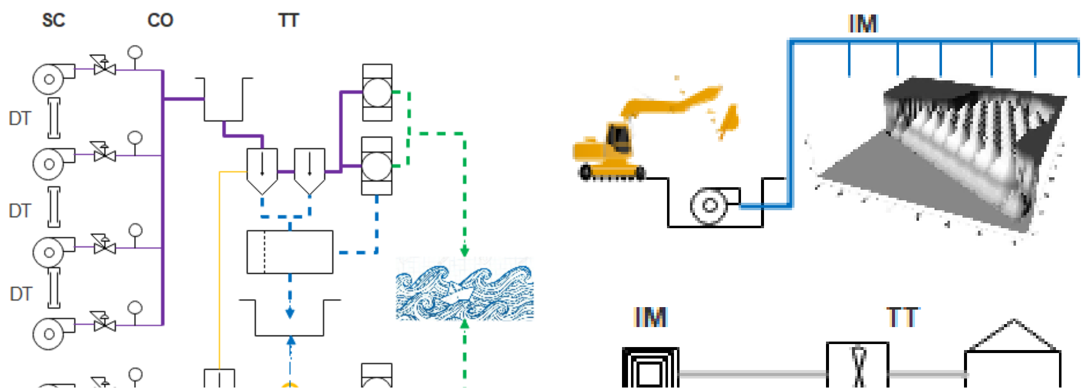


Figure 13 - Water treatment, beach nourishment and air treatment schemas.

Last thing to highlight is that the last-named list of MEP system is not exhaustive. Reports include some other systems such as a heating system for making treatment possible during winter seasons. The author had to limit the modelled equipment because of time issues. Choosing these systems over others is based on their relevance on the 3D coordination activity. As they are still in the design phase, the author's interest was to be aware about possible clashes not only between models of the same discipline but also between models belonging to different disciplines.

2. Information Production

The information production process in a BIM-based project consists in the creation of the Building Information Model. As it was mentioned in the introduction of this thesis, the task assigned to the author was to create the MEP model.

The information production process is generally ruled by a BIM Execution Plan (BEP). The BIM Execution Plan is the response from to contractor company to the contracting one. Inside this document, all the Employer's Information Requirements (EIR) are present. It describes the project objectives as well as the parts involved in the modelling process. It also helps the modeller to realize which information needs to be included. For this reason, the Level of Development must be specified so it guides the modeller at the point where expectation is met.

For doing this thesis, no requirements from ICOP company were provided, consequently, neither a BEP was created. This gave the author a great flexibility in the analysis of the best approach to adopt towards standardization process, for example, in file naming and parameters definition. However, the lack of convention on naming and parameters, create problems when models need to be used for the same purpose.

In order to clarify the information flow during the production process, a diagram where information produced by ICOP company is shown in red while the one produced by the author in blue is presented below.

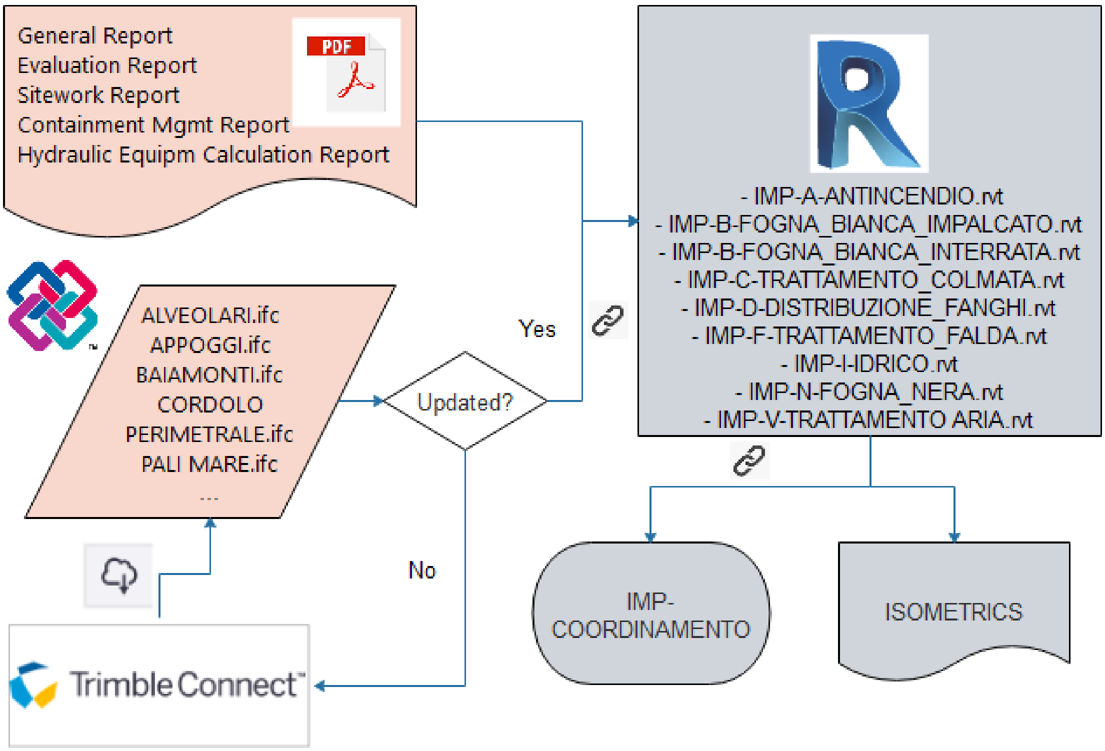


Figure 14 - Information production process.

2.1 First steps

Once it was known that MEP modelling was required, the research for the optimal BIM software to do the task began. This software should be able to model piping and mechanical elements, creating new families and assigning new parameters to them. Other benefits like low PC requirements were considered, since the computing power available to work at home was a limiting factor. The decision was based on the good performance developed through time, the following of openBIM initiative and the student free license availability.

Autodesk Revit

Revit software is specifically built for Building Information Modelling (BIM), empowering design and construction professionals to bring ideas from concept to construction with a coordinated and consistent model-based approach. It includes the functionality of all of the Revit disciplines (architecture, MEP, and structure) in one unified interface.

Autodesk Revit not only satisfies all the previously named requirements, but also has the advantage of being very popular, so it is easy to find video tutorials, guides and forums on whichever language is desired.

Some recommendations for creating the model were taken from the AEC BIM Protocol for Autodesk Revit. This is a unified standard for the AEC industry that also includes a checklist that helps the modeller make sure that the work was done as required in the standard.

Templates

Before starting a new project, the Revit modeller asks for a project template file to be opened. The project template represents the starting point of the new project model. It includes view settings, load families and defined settings. They are saved in an RTE extension file. When IFC links were loaded they displayed in halftone mode, as it was preconfigured in the view of the Plumbing Template.

For the purpose of this thesis, the default Revit Plumbing or Mechanical template was employed. The author then realized that this was not a good idea, since the advantage of having to set once the file was missed. Luckily, forgetting to set up the templates is not a point of no-return. “Transfer Project Standards” in Manage ribbon allows the user to copy the desired settings from other files whenever it is required. Nevertheless, it must be remarked that working this way is time consuming, while working with well-planned templates would have save precious time.

Levels

Default Revit Templates contain 2 levels, named “Level 1” and Level 2”. The platform is horizontally developed, so there is no need to create more levels. It was decided to rename the existent levels to “1 – Sea Level” and “2 – Platform Level”. Almost every element was referred then to Platform Level, since this was the most representative floor level, maintaining sea level was only a way or keeping a reference item.

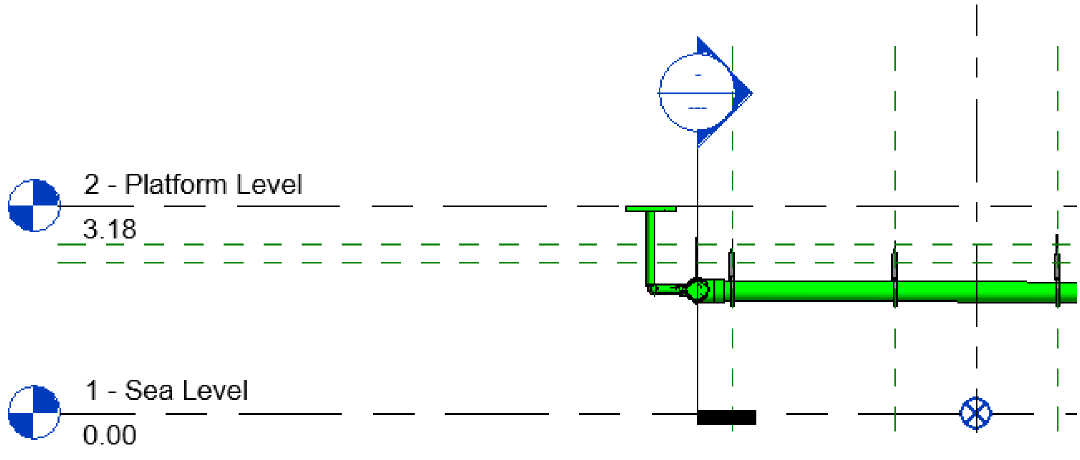


Figure 15 - Created Revit Levels

Work-sharing and collaboration

Work-sharing is defined as a design method that allows multiple team members to work on the same project model at the same time (Autodesk, 2019). More and more frequently AEC industry companies adopt work-sharing as a fundamental policy. This occurs due to the advantages that carries on the collaboration between the different design teams.

There are three kinds of collaboration for Revit 2019:

- **Links**: They present an important advantage respect the importing tool: while making an import inserts a file which will remain the same as when it was imported, a linked file is updated automatically each time the host file is opened, or by updating it in the “manage links” option.

- **Monitor/copy**: This tool is designed for use on a project that involves multiple teams, for example architectural, structural and MEP. It is necessary that all the teams work with Revit software. The Copy/Monitor tool is useful for changing elements like levels, grids, columns, walls, floors, opening and MEP fixtures. By clicking on this option, the model automatically updates these elements if another team changed them before.

- **Worksets**: Another possibility Revit gives to the user for work-sharing activity is to work in different worksets, called Local Models, each one part of a bigger file called Central Model. Rules about how to proceed in this collaboration modality are not trivial, if they are not followed model can become useless. It is very important to create a folder where all the Central and Local Models will be hold. The path to the Central Model as well as the file name must remain the same. Teams must work on Local Models, nobody should work in the Central File. The progress made in a Local Model is not updated automatically in the central model, in the contrary, it is necessary to update changes from time to time. Updating the model allows the other team members to work in real time. To work in this way has a serious disadvantage: as long as the local models become more and more complex the Central Model tends to become heavier, sometimes making impossible for the computer to see all worksets at the same time.

As the other team members were working in a different software (Tekla), I could not obtain the benefits of working with anyone of the two last collaboration tools. The only possible option was to link the IFC files to my model and each time updating was required, new IFC files should be downloaded and saved in the same path and with the same name of the linked file.

A guide made by BuildingSmart® recommends working in different files for each different system, the reason was that it has demonstrated to be the most functional during design and interdisciplinary activities, making changes uploading simpler. So, the entire MEP model has been divided into nine different files, representing the eight different systems modelled. The extra file was created to follow the AEC protocol recommendation of not having files which sizes overcome 200 megabytes.

The RVT extension stands for design projects created in Revit, and it is only openable with the same software, otherwise in AutoCAD which is also made by Autodesk.

The author was the only modeller in a one-person team, so no collaboration in real time was needed. Thus, the decision of linking the different models where made, so to have a guide for the available space for each system.

Linking CAD files

The first step consists on loading the IFC and CAD links. This is found on Revit insert tab.

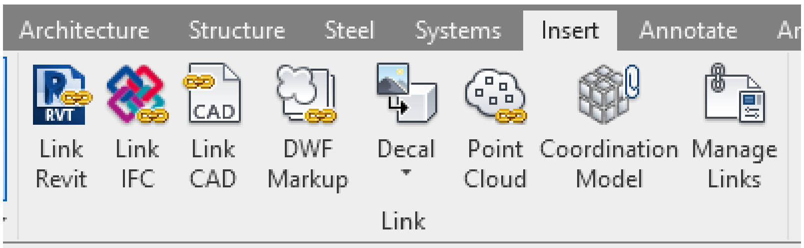


Figure 16 - Revit linking possibilities

The receipted CAD files have been positioned referring to a certain coordinate system. Nevertheless, Revit 2019 has problems with working on huge spaces (more than 33 kilometres) so the correct way to work is with relative coordinates. Because of this the designer was asked to provide the grid employed in Tekla so the author could work with the same coordinate system. The CAD files had to be modified in order to move the design to the (0,0) position of the grid. Then, the linking was done by choosing the automatic: origin to origin option.

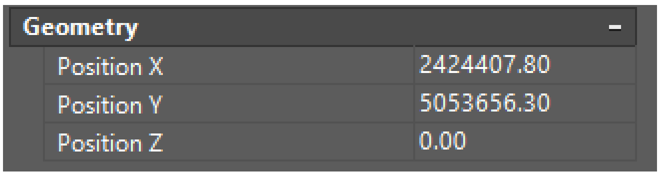


Figure 17 - Original position of CAD's origin.

If for any reason the absolute coordinate system needs to be used, it is always possible to assign coordinates to a specific point in Revit and to introduce an angle between the north of both systems by clicking in “Coordinates” inside the Manage ribbon.

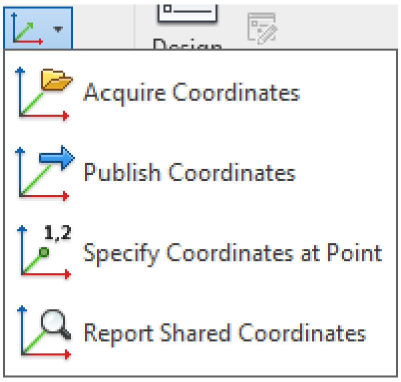


Figure 18 - Coordinates options.

The AEC BIM Protocol for Revit recommends the use of the original coordinates, by publishing and acquiring the coordinates from other projects. However, this option was not used since models in the Common Data Environment were not positioned with absolute coordinates.

Linking IFC Files

The linking of IFC files also helped to verify the coordinate system, since the grid was loaded together with it. The problem on linking the IFC files was that they were so heavy that made linking impossible for Revit. For this reason, only a few models could be linked at the same time. The most important one in term of clash prevention was the perimeter cord. However, in some cases it was necessary to unload and upload other models like the Baiamonti deviation or the rainwater treatment plant for guiding the modeller.

The reason why these models were so huge is the level of development achieved. This is due to the need to obtain detailed structural plans. Another objective of these models might be the calculation of material needed, since every single element has been modelled.

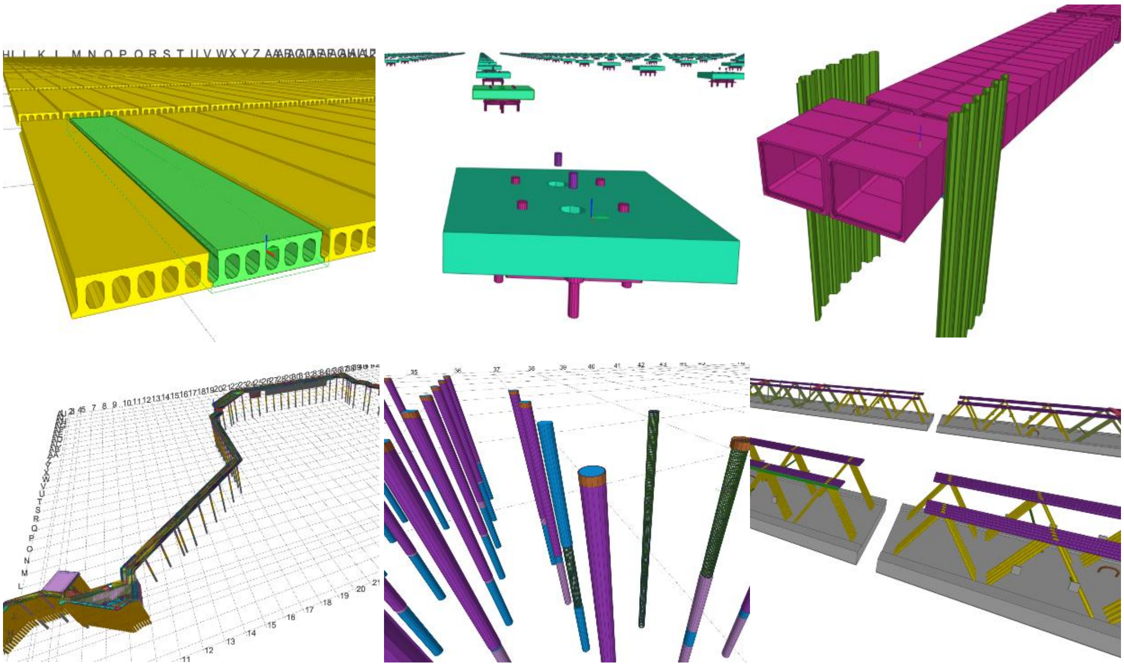


Figure 19 - IFC files: Alveolar panels, supports, Baiamonti deviation, perimetral cord, piles and beams, respectively.

2.2. Naming Conventions

It is very important to clarify some rules about how the information is managed, so productivity of project teams and profitability of the organization increase. Companies are progressively spending resources in training new personnel just to solve problems related to data production. The author has taken some recommendations from the UK standard BS 1192 about how information should be managed. Some other material has been consulted such as Revit MEPContent Style Guide or AEC BIM Protocol for Autodesk Revit.

Folder and Files Naming

Regarding to file naming convention, the BS 1992 standard was consulted. However, the standard is too generic, so the author decided to introduce some changes. The name structure resulted as follows:

<Project>_<Discipline>_<Type>

FIELD	Content	Alternatives	Code
Project	3 capital letters	Trieste's Logistic Platform	PLT
Discipline	3 Capital letters	Architectural	ARC
		Structural	STR
		Equipment	IMP
		Project Management	PRM
		Facility Management	PMG
File Type	3 characters	2D Drawing	CAD
		Coordination	COO
		Databases	DAB
		Documents	DOC
		IFC Models	IFC
		Revit Models	RVT
		Revit Families	RFA
		Project Schedule	SCH
		Tables	XLS

Figure 20 - Folder Naming Convention

The files containing loadable families were saved all together in a folder created thinking on the possibility of being needed in the future. The folder has the relative patch ":/PLT/PLT_IMP/PLT_IMP_RFA". As so many files from different formats have been placed into this folder, the creation of a rule for naming them was considerably suggested. Therefore, the author decided to follow a naming convention, basically:

IMP-<Subdiscipline>-<File_Description>-<Manufacturer>

It must be said that when element modelling was started, the term <Manufacturer> was omitted since this information was still not loaded. When the family's LOD incremented and some specific details about cost or manufacturer were included, this term was added as well.

The term <Subdiscipline> adopt one of the following values:

Subdiscipline	Code
Firefighting	A
Rainwater draining	B
Disposal water treatment	C
Beach Nourishment	D
Groundwater treatment	F
Domestic water	I
Sewerage	N
Air Treatment	V

Figure 21 - File naming subdiscipline convention

For files containing models, the same convention has been made, with the obvious change that no manufacturer is included.

IMP-<Subdiscipline>-<File_Description>

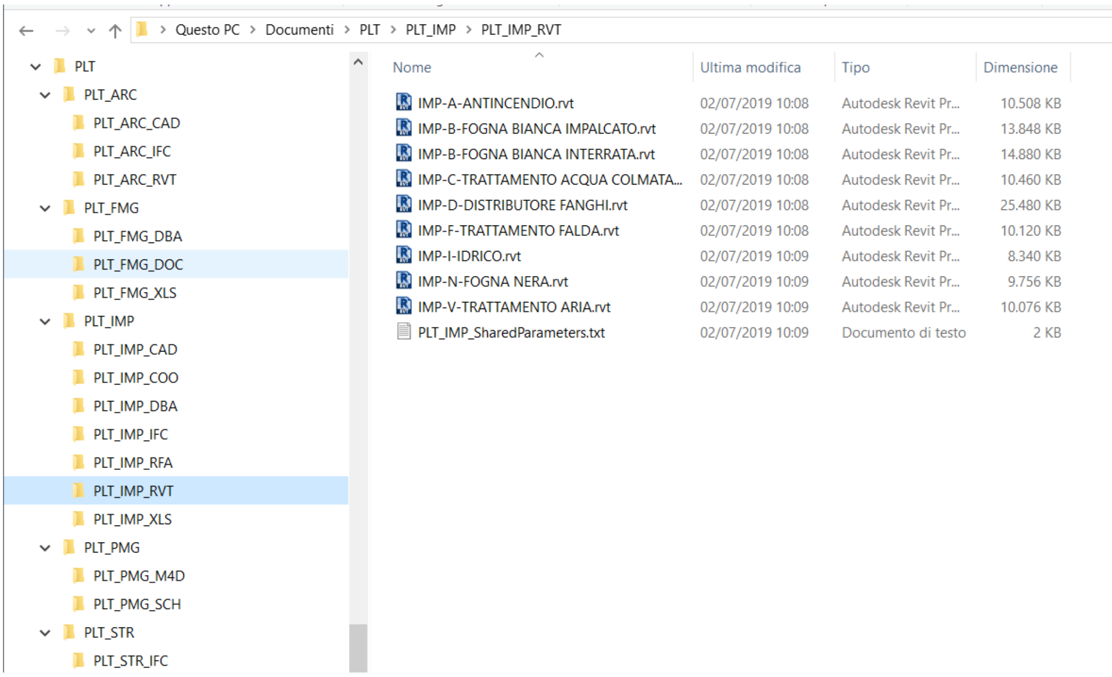


Figure 22 - Files and folders.

Objects Coding

Revit assigns a unique code to each entity modelled, nevertheless, this code is randomly selected. The same happens when the modelled is exported to IFC. In the MVD 2x3 Coordination view 2.3 there is something called "IfcRoot", which assigns a unique ID to every IFC entity once they are created. A random code has no use for the author's purpose, who wants to have every object named so it can be easily identified for asset management purposes. Consequently, a rule of codification has been created, with the structure shown in the following picture:

Level	0
Project	
Piattaforma Logistica Trieste	PLT

Level	1
Discipline	
Structural	S-
Architectural	A-
Equipment	I-
domestic cold water	II
firefighting	IA
rainwater	IB
sewerage	IN
groundwater treatment	IF
dredging	ID
reservoir treatment	IC
air treatment	IV

Level		2
Area		
Platform		IM
Terrain	north	TN
	south	TS
Slope	north	SN
	south	SS
Treatment		TT
Offices		UF
Ro-Ro sector		RR

Level	3
Section	
Slab number	01-54
Subdivision	00-12
Subdivision	00-12
Subdivision	01-24
Subdivision	01-24
Subdivision	01-42
Subdivision	00-22
Subdivision	00-22

Level	4
Function	
Initial	00-09
Intermediate	10-89
Terminal	90-99

Figure 23 - Element's coding structure.

The way to assign this code to each singular element was to create a shared project parameter. This shared parameter was added to the shared parameter TXT file as a “text” parameter type and named as “Code”. The parameter was loaded to all the models and filled with a CAD file created for this purpose. Filling up the Code parameter consisted on, firstly, selecting all the elements on each section of each area and assigning the code until level 3.

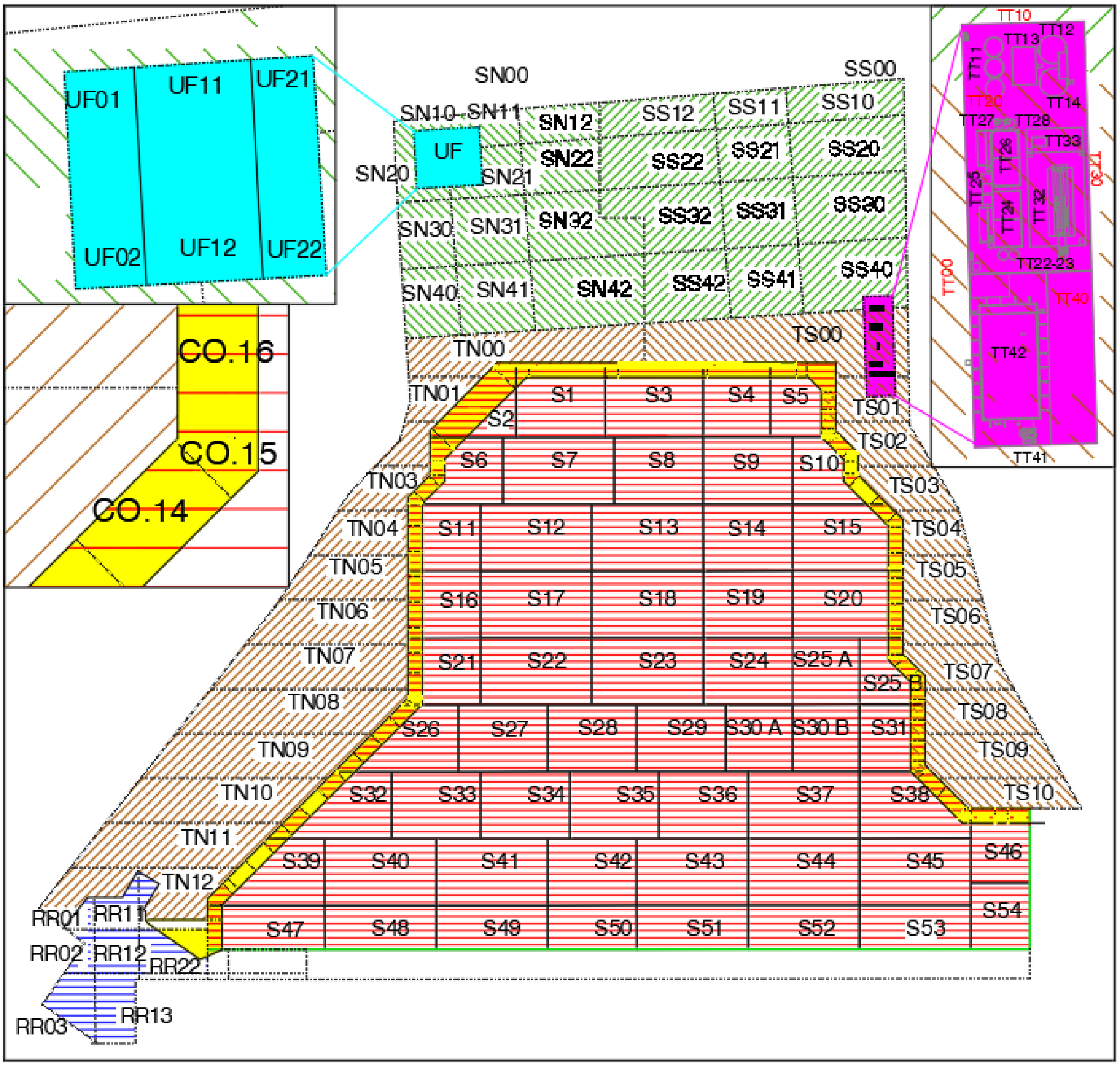


Figure 24 - CAD containing sectorization.

The last level was assigned according to their function in a spreadsheet on Microsoft Excel, avoiding the use of the same code for two different objects. Then, a 6 letters additional level was added to represent the Revit family the object belongs to. This last decision was taken for an easier understanding of the element function.

The most difficult challenge the author had to confront was how to fill the last levels on each element. Modifying thousands of elements one by one was unthinkable since that would have taken too much time, so the idea of filling them by using Revit schedules tool came up. However, Revit schedules do not allow to easily fill cells by dragging click or using formulas between different rows. In addition, the Microsoft Excel export does not come in the predefined Revit software. Fortunately, when searching on the internet, a plug-in for Revit called Import/Export excel made by BIM ONE came up and made that task possible.

View Naming

It may look trivial, but it is not. Having a view naming convention is very useful when working in large projects with an important number of views. The author made his own convention based on some suggestions from standards, but he customized it in order to adapt it to his specific requirements.

To do this, a new group of shared parameters was created, one for each level required. These parameters were then imported into the project as project instance parameters, and the order of being applied just for views, schedules and tables was given. This way, the new parameters would not affect other Revit Entities.

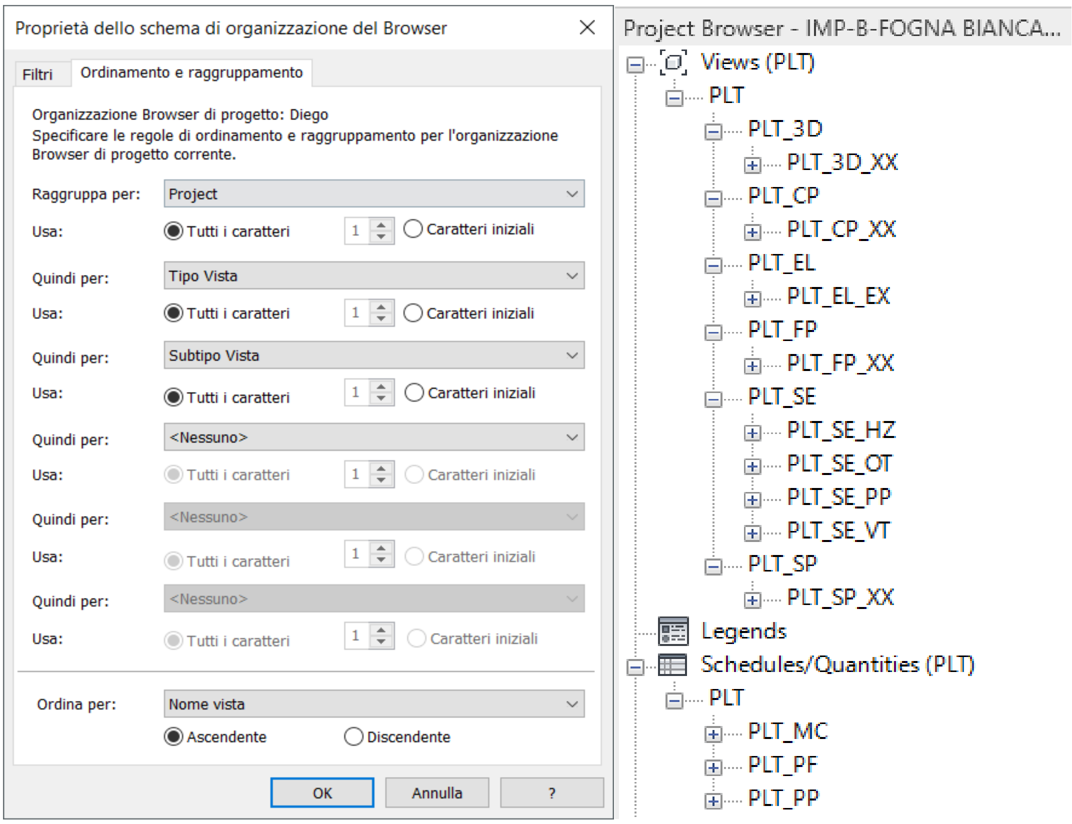


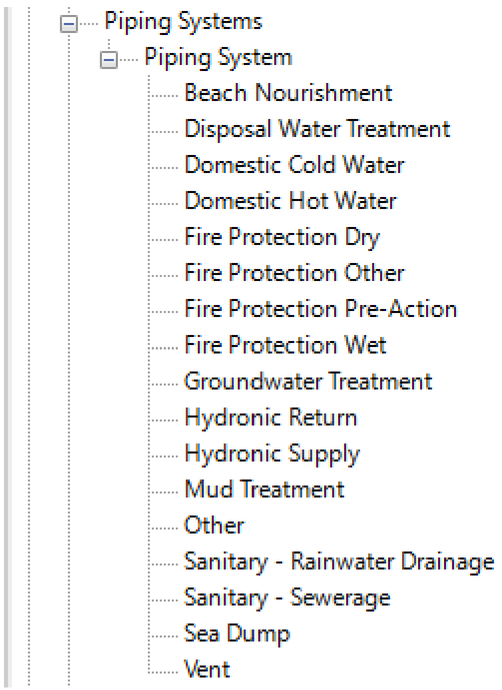
Figure 25 - Revit, view naming convention.

The next step was to set up the browser, creating a new user configuration, one for views and the other for the schedules. This new configuration allows to select a standard for ordering and grouping the views and schedule list. The results are shown in the picture below.

Pipe systems

Pipe systems are logical entities that facilitate calculations for flow and sizing of equipment. They have a hierarchical decomposition that consists on: Classification, type and name. Classification is completely hard-coded into the system, there is a fixed number of them. The ones used in this thesis where: Sanitary, Domestic Cold Water, Fire Protection Wet and Other.

Piping systems types are shown in the browser within all the different categories. It was decided to use the default piping system types whenever possible. However, default system types were not enough for representing all the systems required in the project. Because of this, new types were created, by duplicating the existing ones. The duplicated type obtains the same classification of the original one, so for mapping it to the correct class, the duplication must be done from the correct system type. System types work the same way family types do. They have their own type properties than can be changed from the properties panel, such as graphics, materials or identity data.



Domestic Cold Water	
Fire Protection Wet	
Sanitary - Rainwater	
Sanitary - Sewerage	
Beach Nourishment	
Disposal water treatment	
Groundwater treatment	
Air Treatment	
Sea Dump	
Mud Treatment	

Figure 26 - Piping systems types naming and colour convention.

There can be different piping systems according to each piping system type into the project. This piping systems consists on the group of different element categories: terminal components, break-into components and pipe/ducts component. Equipment can be previously assigned to a piping system, and once all equipment has assigned a piping system, it is possible to generate automatically the system layout using the Generate Layout tool, into the Modify ribbon that appears when the equipment is selected.

To see at all modelled systems on the project, it is necessary to go to the View tab and click on the User Interface option. From there it is possible to select what windows are shown in Revit interface. Among all the possibilities, there is one called System Browser, which is usually turned off. Once it is turned on a list of all systems present in the project is displayed. From there it is possible to change each system name. By default, Revit assign to each system a name consisting on the system type and a number automatically generated. The author decided to be as consistent as possible with the information provided in the planimetries so, for example, in the rainwater drainage system the following convention was employed:

Field	Content	Alternatives	Code
Discipline	1 Letter	Sanitary	**S**
Progressive 1	2 Numbers	From East to West	**01**
			…
			13
Basin	1 Letter	Left	**B**
		Right	**F**
Progressive 2	2 Numbers	Unique	**00**
		Principal	**01**
		Secondary	**02**

Figure 27 - Rainwater piping system naming configuration.

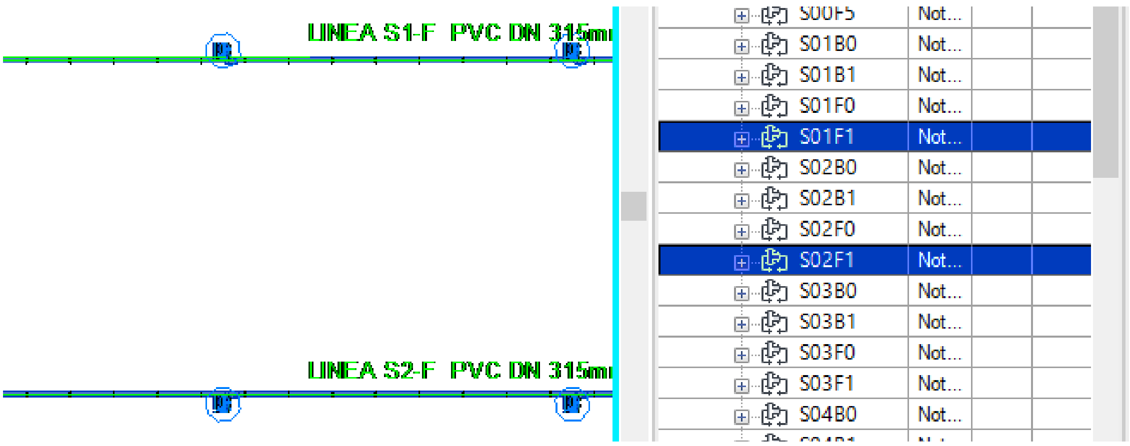


Figure 28 - Revit System Browser.

2.3. Object Creation

Once links are loaded, the next step is to start modelling. The right way for modelling MEP equipment is to first locate the terminal families in the right place. Then, pipes or duct layout is created. In the next paragraphs the methodology employed for creating the Revit models is explained.

Firstly, it is important to introduce some new concepts. Every object created on Revit is technically called “instance”. Each instance corresponds to a hierarchical classification inside Revit that consists on: *Categories*, *Families* and *Types*.

Categories represent the most general classification. Some examples of category are Pipe, Pipe Fitting, or Mechanical Equipment. Depending on the category, a property set for each instance will be provided.

Families are the following subdivision in the string. Inside Revit there are three types of families:

- **System Families:** They are always available in any project, it is impossible neither to remove them nor to load an own version. This is the case of pipes or air ducts in the PLT project.
- **In-place Families:** Created in the Revit project directly, they cannot be saved as a separate file and they cannot have different types. For this project few families have been created this way, for example the overflow tank that collects the water from the confined disposal. It has been decided to make it this way as long as it would not be used more than once, neither in another project.
- **Loadable Families:** These are the most common ones. They can be found on the Revit libraries, on the internet or be designed from scratch at the Family Editor. They are saved with RFA extension as separated files, and they can be also loaded in other projects.

Families have their own “Family parameters”, which depends on the category they are part of. Some of them, nevertheless, are common to every category like “always vertical”, “shared” or “Identify Data parameters”. Omniclass Number and Title are also included.

Subdividing families into *types* is very useful when standardized objects with different dimension or properties are needed. What makes the difference between family types are the “type parameters”, while at the same time, every type shares the same standard parameters of the family, such as Material, Model, Manufacturer and so on. This was, for example, the case of the different pipe supports: There was not only a single type of support, the type depended on the distance between the platform ceiling and the pipe, because different lengths were required. In the CAD used as reference, the different types were identified with different colours, as it can be seen in the following picture:

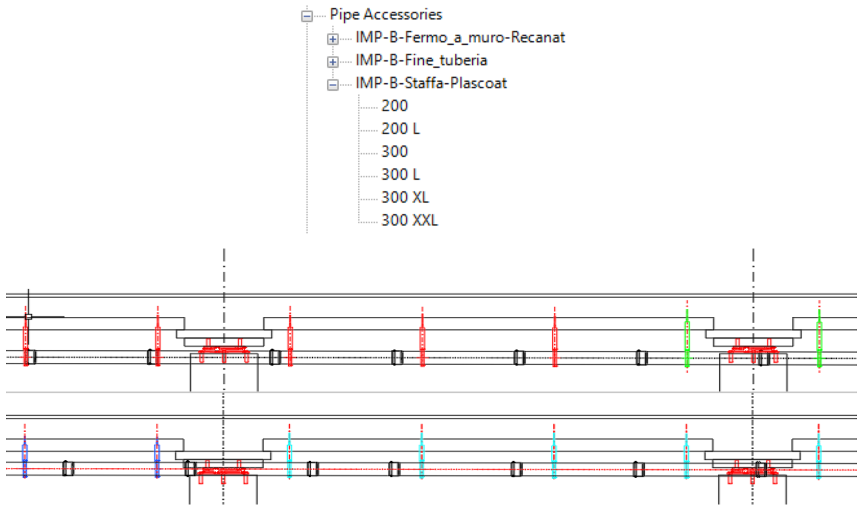


Figure 29 - Types of pipe supports created.

Lastly, *instances* represent the single object placed in the project. They adopt the property set of the category they correspond to, as well as the family and type properties, but that is not all: They can also have instance project parameters. These parameters can be completed into the property panel, when a certain instance is selected.

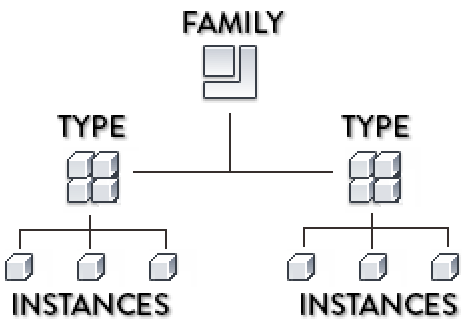


Figure 30 - Hierarchical structure of Revit objects (CADdetails, 2018).

2.3.1. Family Editor

The family editor is a tool inside Revit which has an easy access by double-clicking in a loadable family or by left clicking and selecting the "edit" option. If it is desired to start sketching a new loadable family, the way to do it is by clicking on *file>new>family*.

When a new family is created from scratch, similarly to new projects case, a window asking for the starting template is asked. There are many templates according to the host (e.g. wall, floor, face) and family category. As using hosted families is not recommended, most of the families were created starting from the generic template. However, it must be said that selecting the template is a point of no return: if it is desired to model a face-based family, it must be picked the face-based template. Else, the family would require to be modelled again.

The next step is to pick the category to which the family will take part. Failing in this step is not a problem since it is always possible to change it.

When starting to create the family, the modeller should pay attention to some standards and recommendations for the type desired. They are not strict rules but the result of years of experience of specialist modellers. Some of them are written below:

- Avoid using Speciality equipment Category.
- Use Lookup tables rather than creating separate families.
- File size: No more than 400KB for single objects and 800KB for more complex ones.

They have been taken from the Revit Model Content Style Guide from Autodesk and the European MEPcontent Standard.

Altimetric position

The rest of the information about MEP equipment received consisted on a CAD section of the platform, information taken from the general and evaluation report and the answers to some questions made by phone call to the company's designer, such as:

- Pipes underground must have a covering at least equal to 1 meter from the top of the pipe itself.
- The pavement levels were not indicated on CAD drawings, so the author had to create a longitudinal slope of 1% that connects the space near the platform with the East boundaries in order to meet train tracks design requirements.
- The pipe routing of some systems was not included on CAD drawings, so they were deduced from some designs in the hydraulic systems calculation reports.

While the position of equipment under the platform was already decided, the underground equipment layout was still in design phase. For this reason, a higher level of development was applied to the first one. High level of development models of something that is still in design phase is worthless. In fact, the author made some changes in the layout respect from those received, so it may occur that many modelled elements position differs from the real position.

The following QR code is linked to a video that shows a walkthrough created around the perimetral cord, and finishes up to the platform, in the treatment sector:

Figure 31 - QR code of Revit model Walkthrough.

2.3.2. LOD tables

A list of some of the families created during the modelling of the MEP equipment is shown in appendix 1. It must be mentioned that it is not an exhaustive list, and the criteria for choosing what element to show was based on their development. Level of development is a concept that was born in order to measure the amount of information inside a model.

The first time the expression "Level of Development" as meaning of the acronym LOD came out was in an AIA publication (American Institute of Architects). Its definition represents the usability and limitations of the model under consideration. The AIA organization created a specification with the objective of improving the quality of communication between professionals that work with Building Information Modelling. This new concept made easier to explain which the parts requirements were.

The specification introduces a LOD scale, where each level is identified with a three-digit number. These levels are illustrated in the following picture:.

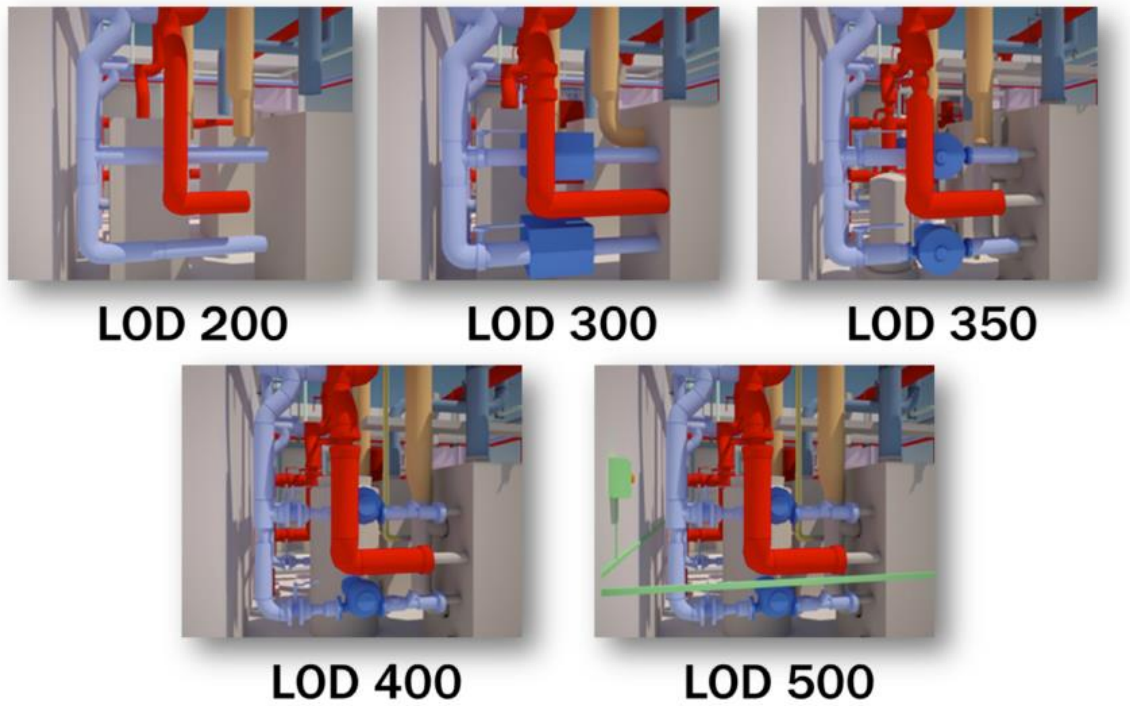


Figure 32 - Levels of Development in a piping project (Hyderabad, 2018).

The specification also mentions the difference between Level of Development and Level of Detail concepts. While the first one can be thought of as the reliable output of the model, the Level of Detail can be thought of as an input to the element. It refers to how much graphical information has been attached to the model's elements.

A model does not have an only LOD, on the contrary, it will have many elements modelled at different levels of development. There is a direct relationship between the project phase and the level of development: in the first steps, just some schematic information will be enough, then as the project becomes more mature, the level of development also improves. This is a progressive evolution that ends in what is called the as-built model, in other words, what is effectively measured on site once the construction process finishes. The optimal workflow consists on starting with a schematic model (LOD100) and then enriching the model step by step. However, to simplify the model is not so easy as it seems since a lot of information from the different construction phases are being received constantly. Is the modeller's responsibility to be aware of which information is introduced and when to do so.

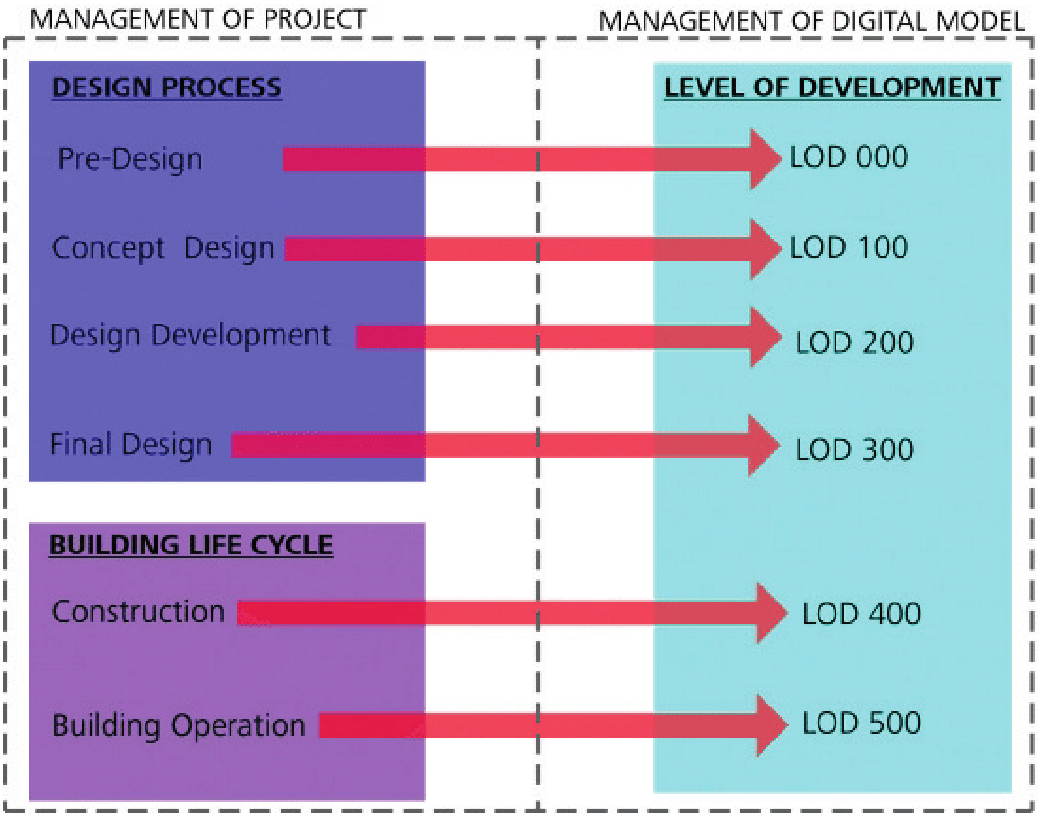


Figure 33 - Level of Development recommended for each project phase (Schweitzer, 2016).

International Standard in development process ISO 19650 has made some changes to Level of Development concept. First, its name has been changed to "Level of information need". The decision was taken by a wide group of readers, where there were many not English native speakers. The reason for this change is to employ a more generic term than LOD. Level of information need is not supposed to be shortened as an acronym. It should determine the quantity, quality and granularity of information. The term is used to define a minimum value for ruling parties' appointments. Anything among this minimum is considered a waste.

In Italy the standard that refers to collaborative digital environment in the AEC industry is UNI 11337 Standard, which last version was released in 2017. The remarkable difference between the AIA specification and the UNI standard lies on the fact that the Italian standard uses a different scale to define the Level of Development. This scale includes two more classifications for level of detail definitions, giving as a result seven categories of LOD. These categories, unlike AIA specification, take their names from alphabetical letters, in the following way:

LOD A: Entities represented by a symbolic geometric system. All their quantitative and qualitative characteristics are indicative.

LOD B: Entities graphically represented as a generic geometric system. Their characteristics are approximative.

LOD C: Entities represented as a defined geometric system. Their characteristics are defined in a generic way, respecting the standards.

LOD D: Entities graphically represented as a detailed geometric system. Their characteristics are specific to similar products.

LOD E: Entities graphically represented as a specific geometric system. Their characteristics are specific to the single definitive product. Also, fabrication, assembly and installation details are defined.

LOD F: The objects express the virtualization of what has been constructed (as-built). Their characteristics are specific to the element cast in place. For each single product the maintenance interventions have been defined.

LOD G: The objects express the virtualization of an element and its state in a certain date. It has been updated from the original as-built element, and it is called as-is.

The difference between the last three categories is non-graphical type. It is just some more information introduced to the entities about their current state, so the user can realize if it is necessary to make any intervention. The correspondence between the AIA specification and the Italian standard is presented below:

AIA specification LOD	UNI-11337
100	A
200	B
300	C
400	D
500	E

Figure 34 - Correspondence between AIA specification and UNI-11337.

It must be highlighted that during this thesis the LOD concept of the Italian standard was employed. It must be also highlighted that UNI 11337 standard will probably be updated in order to adapt the new ISO standard, so the LOD term may also change.

Level of Geometry and Level of Information

Level of Development is divided into two subcategories: Level of Geometry and Level of Information, called LOG and LOI respectively. The first one is related to the graphical representation, while the second one corresponds to the non-graphical information about entities. This classification can be seen in the first column of LOD tables.

Lastly, what is eminently important to understand about LOD concept is the limits to what must be represented. It does not make sense putting a lot of effort in making the model look as realistic as possible if it is not required. The use of an excessive level of detail and plenty of information in a model may be the worst mistake the modeller can commit.

2.3.3. Pipe Modelling

Once terminal elements are placed, the following step is to join them in order to create the piping systems. The author strongly recommends connecting first all the equipment with pipe or duct placeholders. By choosing this option, a schematic idea of where pipes will be positioned can be made. They can also be scheduled and assigned to systems, as well as their types and properties can be changed or edited. Pipe placeholders make introducing changes easier, since they do not have pipe fittings. This way, possible errors like changes on fitting directions may not occur. In conclusion, it can be said that pipe and duct placeholders have all the advantages of pipes and ducts, while the only disadvantage they present is visual (they are represented as a line).

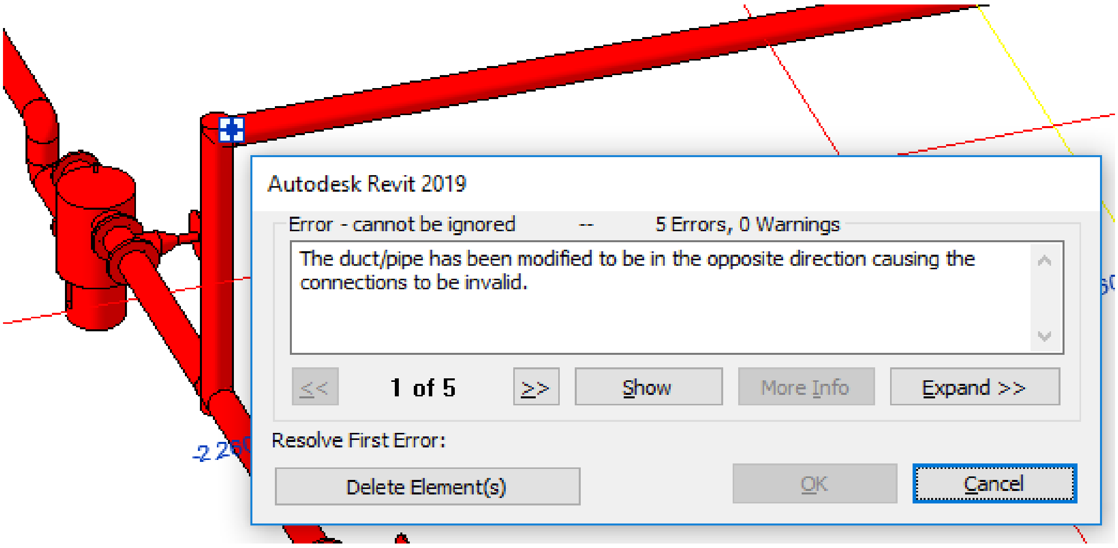


Figure 35 - Error avoided when using pipe or duct placeholders.

Once the schematic design is finished, the next step is to transform the pipe placeholders into real pipes. This becomes a point of no-return, so the author recommends doing it only if no more important changes in the layout will made. This is done by clicking on a pipe placeholder and using the "Convert Placeholder" tool.

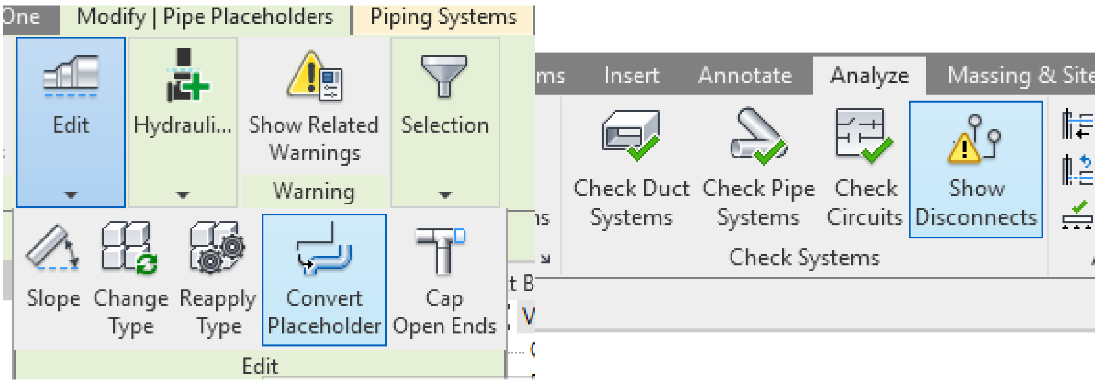


Figure 36 - In the left, the Placeholder Modify tools. In the right, the Show Disconnects tool.

While drawing the piping system, the best practice is to have checked the "Show Disconnects" option, since this helps the modeller to realize if there is any problem in the piping system that do not allow to close the system. These problems can occur due to a disconnection or inconsistency between systems, when trying to connect two elements from two different classification system. It is possible to find this tool in the Analyze tab, on the Check System panel.

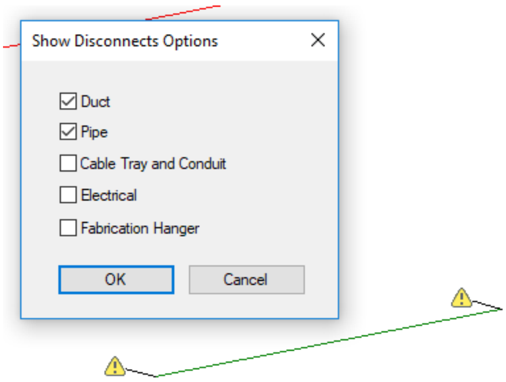


Figure 37 - Disconnection alerts displayed for a pipe placeholder.

Consequently, pipes elements were created adopting the same type and properties than the placeholder has. Pipe elements belong to the "pipe" category, where all families correspond to System Families type. Only types can be created, modifying some settings such as the routing preferences.

Routing preferences

Routing preferences allow to select the default pipe fittings that will be placed during the use of this type of pipe. It is possible to load the required pipe fitting families from the libraries, since they are loadable families. Some other settings can be also customized: Angles, Conversion, Segment and Sizes, Fluid, Slopes and Calculation. These settings are saved into Revit model and can be easily checked in the Manage ribbon, on the Settings panel. There, the option "MEP settings" can be found. From there it is possible to access either to Duct and Pipe settings.

Initially the modelling was done by using commercial angles types, the problem was that this made impossible to follow the CAD planimetry accurately. For this reason, the "Use any angle" option was selected. This was a mistake, since the planimetry provided, as it was remarked previously, was in the design phase and the reality is that fittings have a discretized list of possible angles. Fortunately, no important issues came up from this decision, since the parameters selected where independent from the angle. However, this would have been an important error in models whose objective is to compute costs, because fitting costs varies depending on its angle.

Segment and sizes were the next properties to set up. For PVC pipes, the value was provided in the commercial catalogue. For the HDPE and Concrete pipes, on the contrary, sizes were taken from catalogues of Italian manufacturers found on the internet. This detail was included only with the purpose of making the model more realistic, so a more accurate clash detection is then obtained.

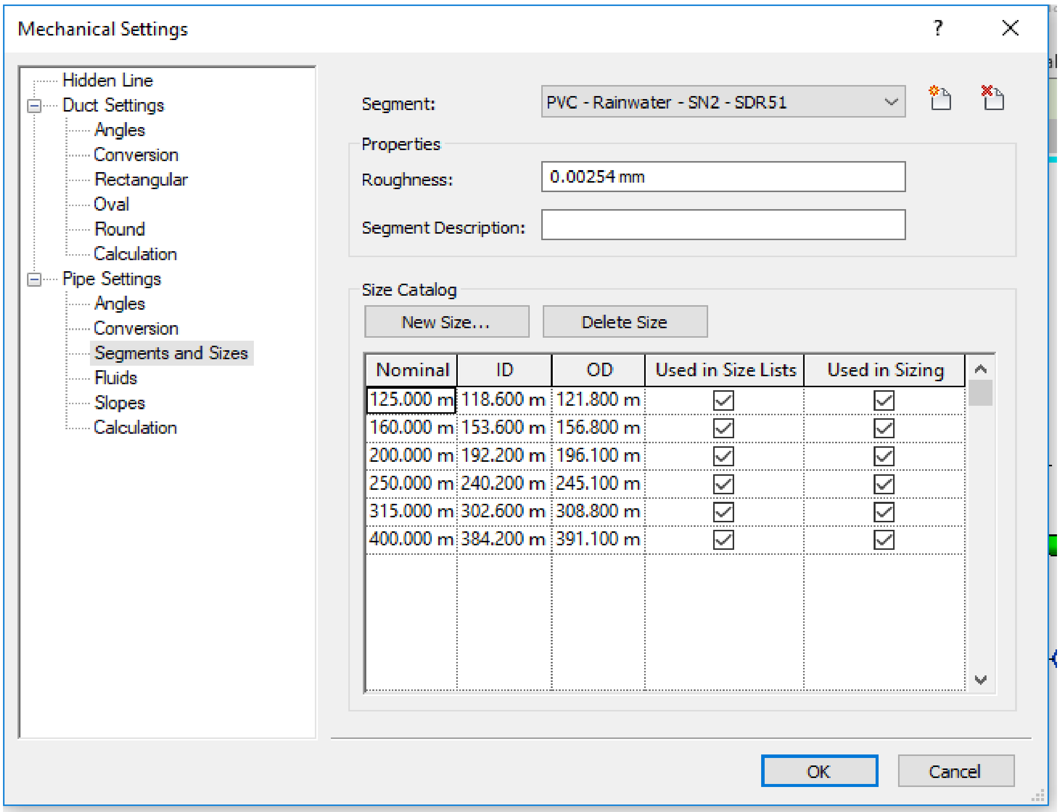


Figure 38 - Revit, customizing pipe sizes.

The last routing preference to be set up was the slope, since the 0,2% slope of the sewage and rainwater drainage system was not included into the default ones.

2.4. Parameter assignment

Before starting the information production process, planning which parameters need to be included for the model scope should be done. They can be inserted into a template so every time a new file is created, it is not necessary to create the parameters again. It is true that it is always possible to copy the standards from another file but by working this way a lot of time can be saved.

The different types of parameters and their characteristics were already mentioned in the Revit introduction paragraphs. This apart explains the different parameters the author decided to include to the model. In order to avoid having different parameters names among the different model files, it is crucial the use of "Shared parameters". Having different names or field types for parameters would generate important issues, like not being able to schedule them in the federated model. This concept improves information consistency.

Shared parameters can be used in multiple families and projects. These types of parameters are saved into a TXT extension file. For the purpose of this thesis, a unique file was created where parameters were divided into groups. It is possible to create or modify a TXT file from Revit, using the tool "Shared Parameters" into the Manage ribbon. The groups present in this file are described below.

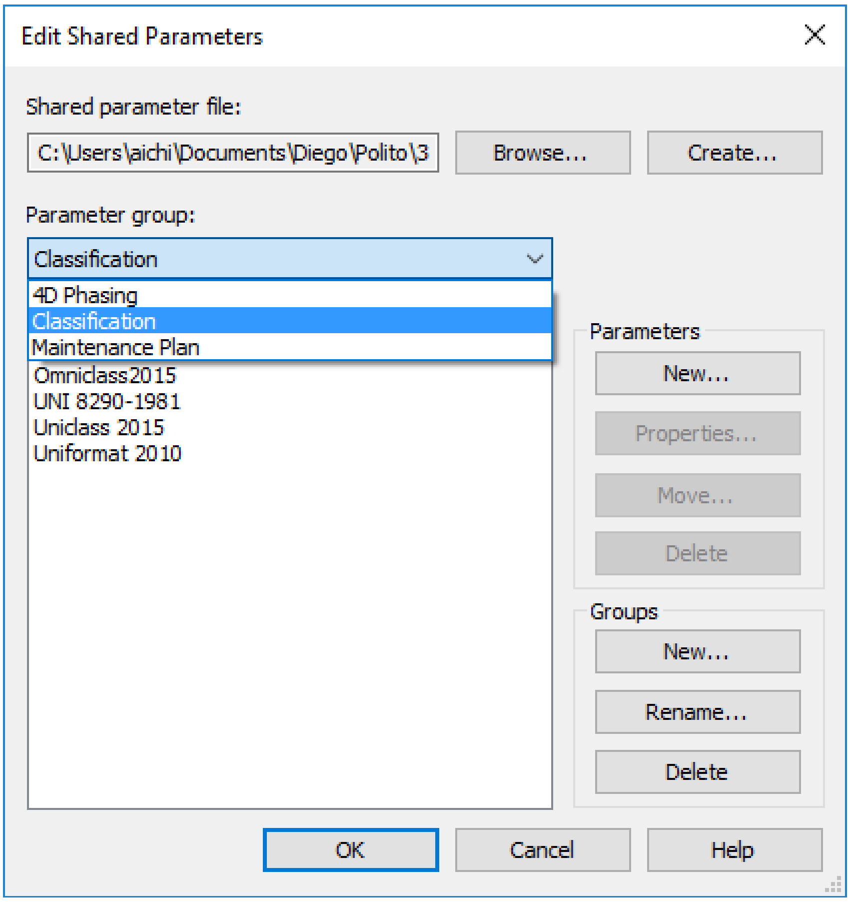


Figure 39 - Shared Parameters file showed inside Revit.

Phasing and Maintenance Parameters

This group includes all parameters employed for the information management. The one referring to 4D analysis is the “WBS” instance parameter, which will then be explained in detail. For the maintenance plan linking, the fundamental type parameter employed was “Maintenance element”. This parameter is the one that identifies each type with its equivalent in the maintenance plan. Some other parameters related to the maintenance activity were introduced, however they are explained on the model application chapter.

IFC parameters

These parameters were created in order to correctly class map the different Revit elements when they are exported to an IFC extension file. The reason for their use is an inconsistency found between Revit categories and IFC classes, which is treated with more detail on the information delivery chapter.

2.4.1. Classification Parameters

In the AEC industry, classification is used in multiple activities, such as information production, schedules, information management or operation and maintenance information. A guide about classification underlines that without any classification, finding objects become very difficult. At the same time, naming strategies may sound intuitive for the person that created it, while for the rest of the people may not be so obvious (Sands, 2017).

Globalization has transformed the way companies do business, and these phenomena is also present in the AEC Industry. Imagine it is necessary to replace a certain element: the existence of market with lots of manufacturers from all around the world, allows to search between lots of different products with different quality level and origin. The existence of classification systems appeared to improve the communication between different companies.

They all have similar structure for codifying objects, consisting on subdivisions that the author will call levels, despite of having a different name for each specification. The classification code length depends on how much levels are considered. The longer this code is, the more specific the object is.

It must be remarked that for the purpose of this thesis only elements or products were classified. However, objects concept not only includes products, it may also include activities, spaces, systems or complexes, for example.

ISO 12006-2:2015 is the international standard that defines a framework for the development of built environment classification systems. The standard does not provide an own classification system, it just includes some recommendations about how to create them. It was used for creating some of the actual national classification systems. A classification system works like a common language, so the existence of many of them is a disadvantage in terms of interoperability. Some of these national classification systems are described below:

Uniclass 2015:

Unified classification for the UK industry that consists on tables that include every item from any scale. It is the result of collaboration between different experts from AEC industry, where for the first time buildings, landscape and infrastructure can all be classified under one unified scheme. It has been structured in a flexible way in case it becomes necessary to include any classification requirement in the future (Delany, 2017).

The BS EN ISO 19650 series of standards include the classification as a requirement for all BIM projects.

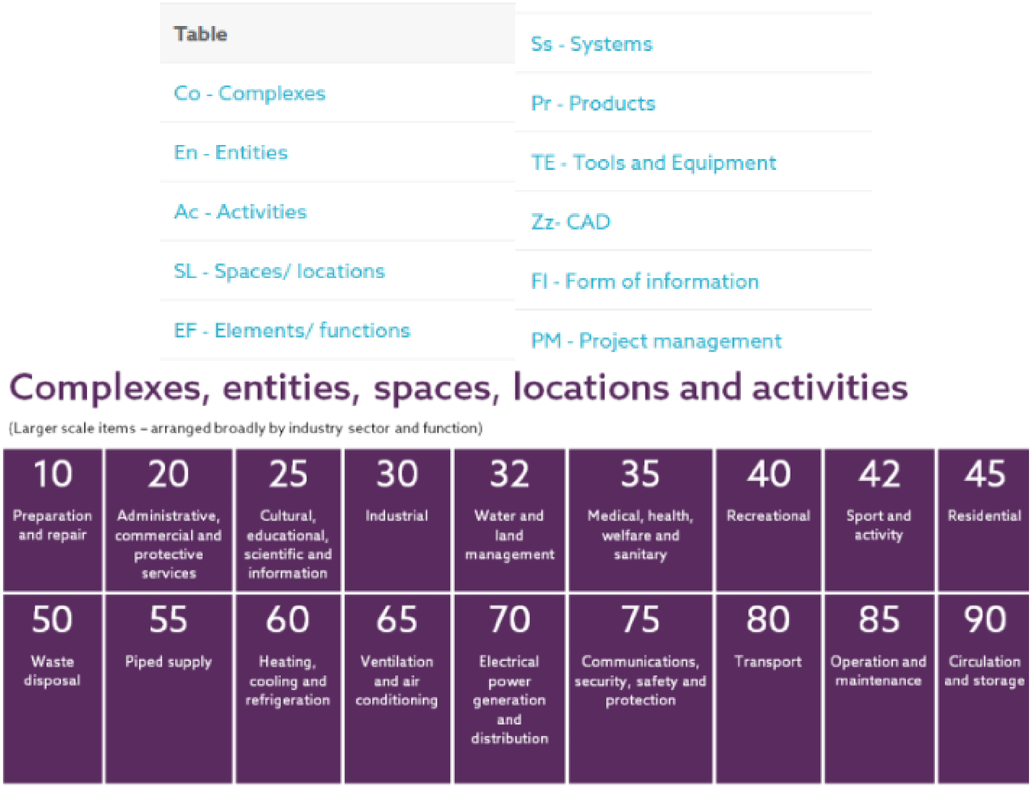


Figure 40 - Uniclass 2015 two first levels (BIM-Level2, s.f.).

The main starting point are Entities, which are composed of Elements; Elements are made up of Systems which contain Products. Entities can be described by using the Spaces and Activities tables, and at a more general level the Complexes table contains terms that can be thought as groupings of Entities, Activities and Spaces.

Omniclass:

Created by the OCCS Development Committee, it is the North American equivalent to Uniclass classification system (Buidinginformationmanagement, 2013). When it was created, developers pretended to combine multiple classification systems in order to obtain a unique one, based on ISO 12006-2 standard. It was thought to fulfil its purpose for the full project life cycle. Fifteen inter-related tables each one representing a different facet of construction information are presented in its inside.

Omniclass is currently implemented in project and resources such as the National BIM Standard of the United States (NBIMS-US), the Construction-Operations Building Information Exchange (COBie), the LOD specification, among others. It has the advantage of being flexible as it is not a hierarchical system, on the contrary, it is possible to combine different facets in order to obtain new elements that may appear. The idea is to cover all new possibilities in the AEC industry, avoiding accumulated new elements in "other" classification that has no place in hierarchy systems.

- Table 11 - Construction Entities by Function
- Table 31 - Phases

- Table 12 - Construction Entities by Form
- Table 13 - Spaces by Function
- Table 14 - Spaces by Form
- Table 21 - Elements
- Table 22 - Work Results
- Table 23 - Products
- Table 32 - Services
- Table 33 - Disciplines
- Table 34 - Organizational Roles
- Table 35 - Tools
- Table 36 - Information
- Table 41 - Materials
- Table 49 - Properties

Figure 41 - Omniclass tables list.

Autodesk, the popular BIM software developer born in the United States, decided to include into Revit 2019 structure Omniclass classification table number 23, which correspond to "products". Products are defined in the standard as "basic building blocks used for construction". A product may be a single manufactured item, a manufactured assembly consisting of many parts, or a manufactured operational stand-alone system.

It is possible to assign an Omniclass code to Revit objects into the family properties. They figure as "Omniclass Code" and "Omniclass Type". However, these properties are not updated to the latest version (released on 2015), so many modelled elements are classified in a generic way. Anyway, Omniclass on its introduction encourages users to adopt more subdivisions when necessary, as long as the enumeration rules remain.

Uniformat

Uniformat is a specification created by the Construction Specifications Institute (CSI) and the Construction Specifications Canada (CSC). It has the particularity of being based on components and systems, making it more popular between contractors, as it adapts very well to costs control. The first level classifies information into one of these systems:

A	SUBSTRUCTURE	E	EQUIPMENT AND FURNISHINGS
B	SHELL	F	SPECIAL CONSTRUCTION AND DEMOLITION
C	INTERIORS	G	BUILDING SITEWORK
D	SERVICES	Z	GENERAL

Figure 42 - First level division in Uniformat 2010 Classification.

Next three levels consist on two numerical digits, while the fifth and last level are represented by two alphabetical digits as the following picture shows:

A	SUBSTRUCTURE	Level 1
A10	Foundations	Level 2
A1010	Standard Foundations	Level 3
A1010.10	Wall Foundations	Level 4
A1010.10.CF	Continuous Footings	Level 5

Figure 43 - Example of different grades of specification for Uniformat.

The tables used in this thesis were the ones released on 2010. This version has the particularity of presenting both Uniformat and Masterformat codes, named “UF number” and “MF number”.

Masterformat

The standard was first released in 1975, by the same developers than Uniformat standard, CSI and CSC. It is the specifications-writing standard for most commercial building design and construction projects in North America based on activities and deliverables. Compared to Uniformat, Masterformat is more popular among designers because of its adaptability to technical specifications and project management systems.

Before 2004, Masterformat classification consisted of sixteen divisions, but afterwards the number of classifications used until today were created, with the exception of the 40th division, dedicated to “process integration”. Although having the 2010 version in the Uniformat tables, it was decided to use 2010 as a guide and then update them to the 2014 version.

It is structured in groups, subgroups, division (1st level) and titles (2nd and 3rd levels). In a project manual application, titles are called sections, which specify “work results”. These work results are permanent or temporary aspects of construction projects achieved in the production stage or by subsequent alteration, maintenance or demolition processes.

Figure 44 - Masterformat 2014 divisions index.

UNI-8290

UNI 11337 standard in its second part will define the classification and naming criteria for models, products and processes. However, it is still in design phase. Because of this, until its publication, the Italian standard that recommends the way to classify residential buildings elements is UNI-8290, which is divided into 3 different parts, released on 1981, 1983 and 1987. The first part contains the classification systems. It consists on one table, with only three levels of classification. The classification is significantly less exhaustive than the UK and North America standards. It can easily be appreciated how outdated the standard is by looking at the following table:

EDILIZIA RESIDENZIALE - SISTEMA TECNOLOGICO
CLASSIFICAZIONE E TERMINOLOGIA (NORMA UNI 8290 - 1981)

Classi di unità tecnologiche	Unità tecnologiche	Classi di elementi tecnici
5. Impianto di fornitura servizi	**5.1** Impianto di climatizzazione	**5.1.1** Alimentazione **5.1.2** Gruppi termici **5.1.3** Centrali di trattamento fluidi **5.1.4** Reti di distribuzione e terminali **5.1.5** Reti di scarico condensa **5.1.6** Canne di esalazione
	5.2 Impianto idrosanitario	**5.2.1** Allacciamenti **5.2.2** Macchine idrauliche **5.2.3** Accumuli **5.2.4** Riscaldatori **5.2.5** Reti di distribuzione acqua fredda e terminali **5.2.6** Reti di distribuzione acqua calda e terminali **5.2.7** Reti di ricircolo dell'acqua calda **5.2.8** Apparecchi sanitari
	5.3 Reti di smaltimento liquidi	**5.3.1** Reti di scarico acque fecali **5.3.2** Reti di scarico acque domestiche **5.3.3** Reti di scarico acque meteoriche **5.3.4** Reti di ventilazione secondaria
5. Impianto di fornitura servizi (segue)	**5.4** Impianto di smaltimento aeriformi	**5.4.1** Alimentazione **5.4.2** Macchine **5.4.3** Reti di canalizzazione
	5.5 Impianto di smaltimento solidi	**5.5.1** Canne di caduta **5.5.2** Canne di esalazione
	5.6 Impianto di distribuzione gas	**5.6.1** Allacciamenti **5.6.2** Reti di distribuzione e terminali
	5.7 Impianto elettrico	**5.7.1** Alimentazione **5.7.2** Allacciamenti **5.7.3** Apparecchiature elettriche **5.7.4** Reti di distribuzione e terminali
	5.8 Impianto di telecomunicazioni	**5.8.1** Alimentazione **5.8.2** Macchine **5.8.3** Reti di distribuzione e terminali
	5.9 Impianto fisso di trasporto	**5.8.1** Alimentazione **5.8.2** Macchine **5.8.3** Parti mobili
6. Impianto di sicurezza	**6.1** Impianto antincendio	**6.1.1** Allacciamenti **6.1.2** Rilevatori e trasduttori **6.1.3** Reti di distribuzione e terminali **6.1.4** Allarmi
	6.2 Impianto di messa a terra	**6.2.1** Reti di raccolta **6.2.2** Dispersori
	6.3 Impianto parafulmine	**6.3.1** Elementi di captazione **6.3.2** Rete **6.3.3** Dispersori
	6.4 Impianto antifurto ed antiintrusione	**6.4.1** Alimentazione **6.4.2** Rivelatori e trasduttori **6.4.3** Rete **6.4.4** Allarmi

Figure 45 - Cropped UNI 8190-1981 standard showing equipment decomposition

It must be highlighted that they are standards, it is not an obligation for the designer to follow them, but a recommendation. When it is decided to work with a level 2 BIM model, however, British standards consider the use of Uniformat code as essential. For the study case of this thesis the author decided to input all the different classification systems, in order to analyse the advantages and disadvantages that each one presents. Classification parameters inside were created as “Text” type parameter and saved into the shared parameters TXT file.

As they are getting increasing popularity on BIM projects, a critic for Revit developers must be done. The author considers that these parameters should be included into the predefined ones. On BIM phorums, different professionals’ comments recommend the use of the predefined parameters to assign these codes, such as “Assembly Code” for Masterformat and “Comments” for Uniformat.

For the purpose of this thesis the parameters were introduced as a Project type parameter. After filling each parameter with the corresponding value, a better way to proceed was discovered. The disadvantage of working this way is that these parameters fields are filled only for the project file, making necessary to fill them again each time a new project is opened. The best way to include these parameters is on the family editor, by including them on the RVA file. This way, every time the family is inserted into another project, time for filling the parameters fields can be saved.

The best solution would be that manufacturers make their own families and upload them on an internet library, that could avoid the manual loading of family information. This is the objective that webpages, such as BimObject or MEPContent, are trying to achieve. It is possible to download from there family files in order to load them into the project. However, it is not so developed since not many manufacturers have joined the initiative.

To sum up, a comparison table is presented below:

	Uniclass	**Uniformat**	**Masterformat**	**OmniClass**	**UNI-8290**
Author	National Building Specificatio n (UK)	CSI and CSC (US and Canada)	CSI and CSC (US and Canada)	OCCS Developme nt Committee (US)	Ente Italiano di Normazione (Italy)
Level 1	7 core tables, 4 additional tables - 2 letters	9 elements - 1 letter	50 Divisions, 5 subgroups - 2 numbers	15 tables - 2 numbers	8 Classes of Technological Units - 1 number
Subdivi ded by	Classes of information	Functional Elements	Work results	Classes of information	Technological Systems - functions
Max N° of levels	5	5	4	8	3
Exampl e	Pr_70_55_9 7_01 *(Above-ground fire hydrants)*	A1010.10.C F *(Continous Footing)*	22 11 23.23 *(Domestic-Water In-Line Pumps)*	23.13.31.21. 13.11.11.15 *(Steel bar stressing tendons)*	6.1.3 *(Distribution and terminal systems - Fire protection)*

Figure 46 - Comparison table between classifications.

2.5. Federated Model

The AEC BIM Protocol for Revit suggests employing a model where all models corresponding to the same project are contained, for the benefit of collaboration and clash detection. The advantage of doing this is to easily check possible clashes whenever is required. A federated model was created to host all the models developed about the project. Structural and architectural models extracted from the Common Data Environment are also included. The inclusion is made by links.

Some model external to MEP have also been model to help creating the piping and ducting layout. This was the case of the site, concrete decks, and piles. The last one had to be created since the IFC file was impossible to load it in Revit.

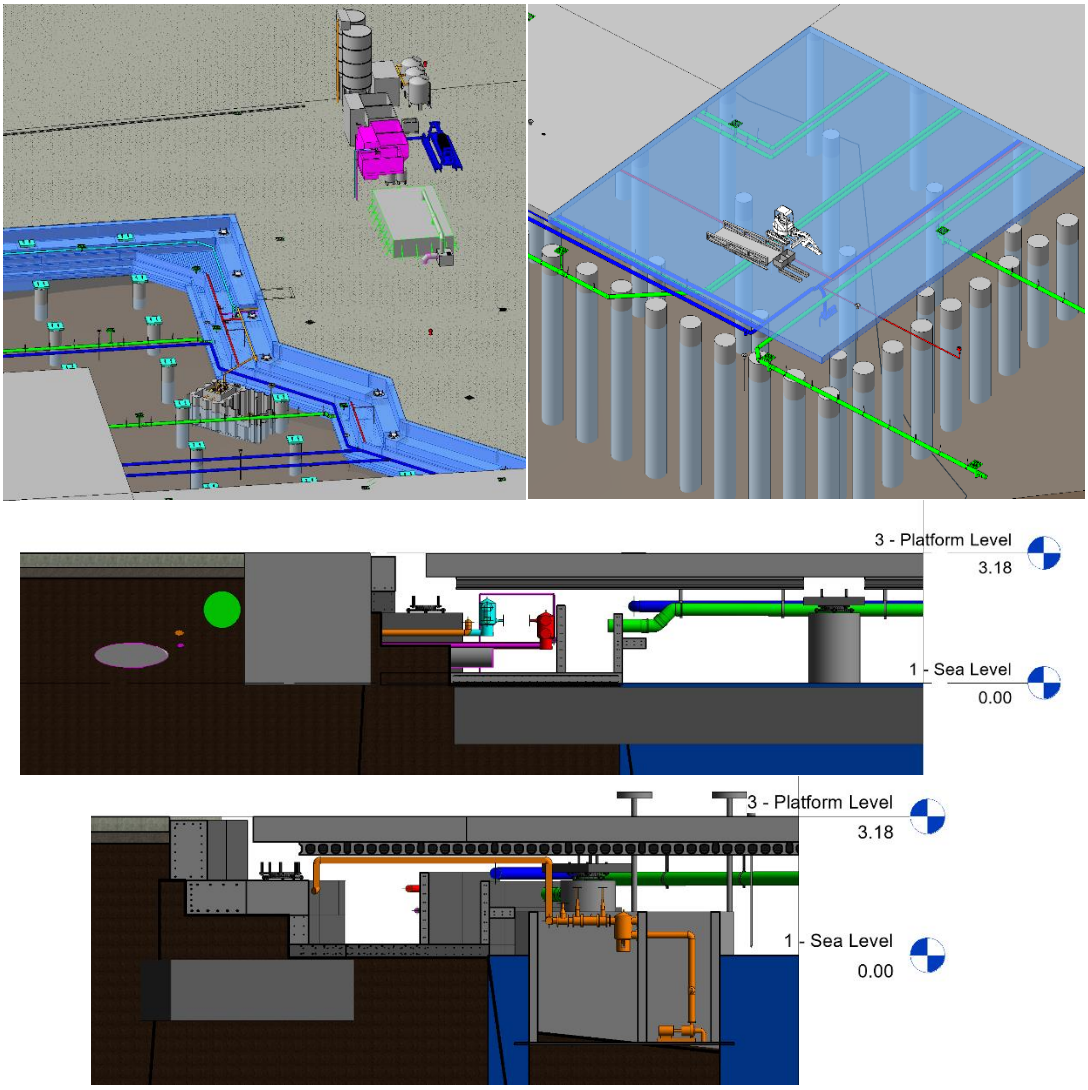


Figure 47 - Revit Federated Model captions

In the federated model each model linked maintains its integrity. It is possible to click in the single object in order to get its properties but modifying them is not possible. It is beneficial for publishing coordinates since once their coordinates are published, the rest of the models can acquire coordinates from it. This has been very useful since acquiring coordinates from IFC files was impossible.

3. Information Delivering

The Information delivery process is basically the uploading of the models into the Common Data Environment process. British standard PAS 1192 recommends the use of a Master Information Delivery Plan, which is used to manage the delivery of information during the project lifecycle. This MIDP is formed by a group of Task Information Delivery plan, which are prepared by team members in order to specify the protocol and procedure that should be followed (Scotish Futures Trust).

The designers of Trieste's Logistical Platform shared their models throughout a collaborative platform and gave the author permission to download files from it as well as upload material to it. The BIM software tool used for modelling (Revit) and the CDE (Trimble Connect) were developed by different firms. This fact became an issue when trying to upload the models.

The exporting process from Revit to IFC is not a trivial process, since they act like two different languages. Although they have some similarities, it took many tries until all the information was exported as required.

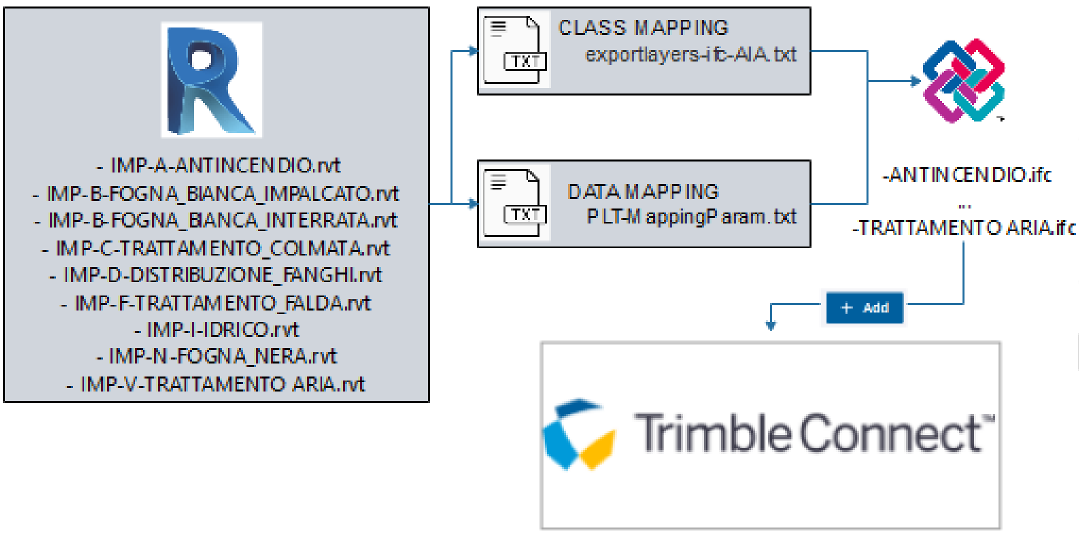


Figure 48 - Information delivering process.

3.1 Trimble Connect

Trimble connect is the name of the collaborative environment produced by the company Trimble. It allows designers, constructors, owners, and operative workers not only to share their projects, but also to see those shared with them in a collaborative view where comments and drafts are allowed. It is also useful for in-place working, since it is possible to access the platform offline (Trimble Connect).

The decision of the company to use this CDE was surely taken for interoperability reasons, since the structural models where made on Tekla, a BIM software tool developed by the same firm.

Trimble enumerates on its page all the extension files supported by the platform. As it could be imagined, the RVT extension was not included, as it is an Autodesk specific format. Fortunately, both Trimble and Autodesk have joined BuildingSMART's initiative and the possibility of sharing the information via IFC format is provided.

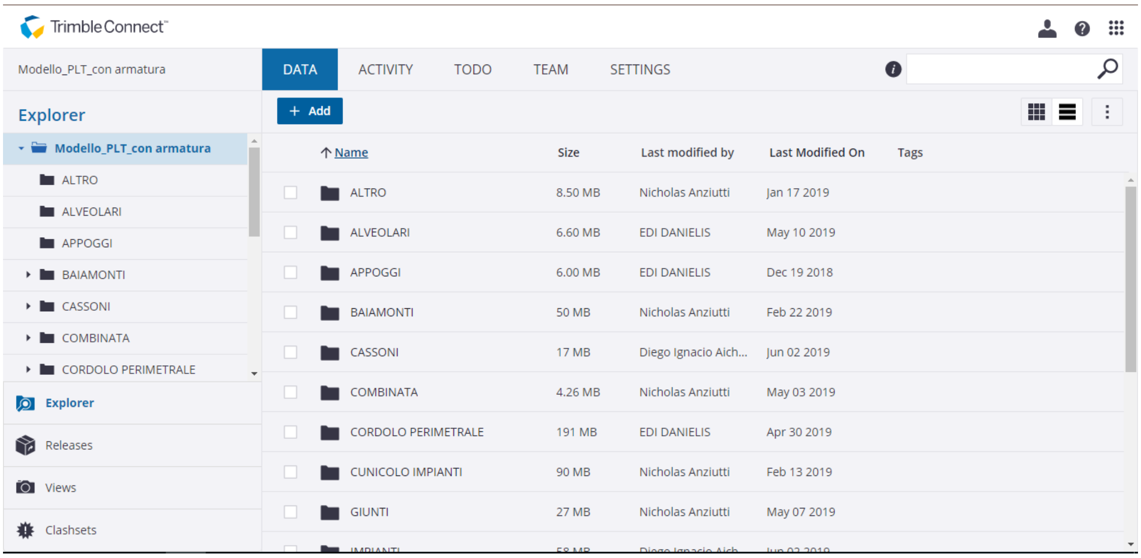


Figure 49 - Trimble connect web version's interface.

An invitation to join the project arrived via email. It was required to create an account in order to be accepted as a user and to have access to the files. The new user was created while it was assigned to it the "simple user" role.

There are two kinds of user within the platform: administrators and simple users. The administrator role is generally adopted by the BIM manager, who is in charge of creating groups and assigning users to the correspondent group. Generally, the groups represent different task teams in an organization. Administrators can assign tasks to each group, which appear enumerated in the folder "ToDo". Finally, one of the most important functions of the administrator is the permissions management, which consists of deciding which group is able to see and which one to modify each folder.

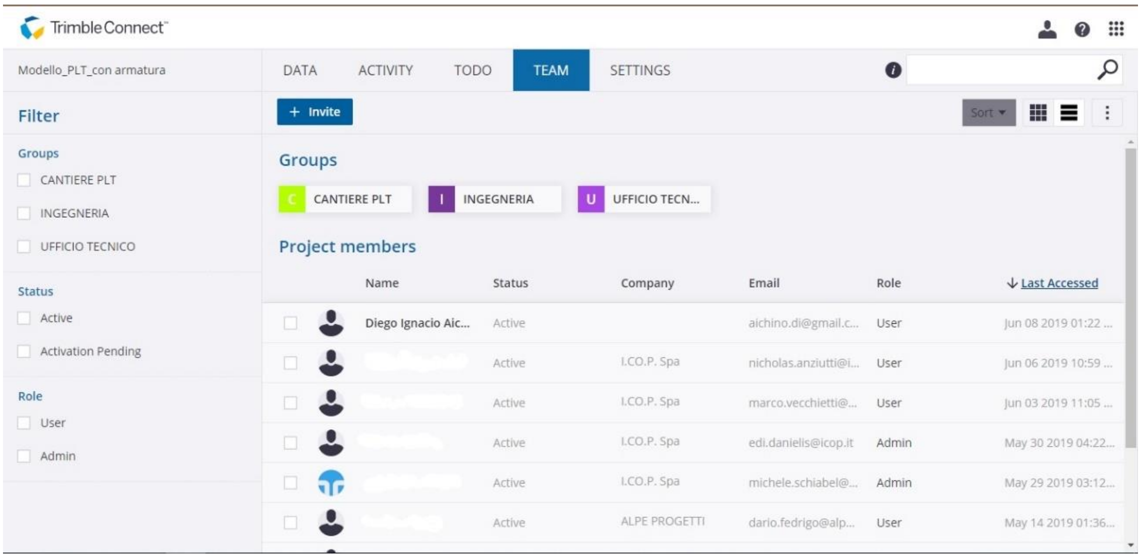


Figure 50 - Trimble Connect teams

Trimble Connect can be used in three different ways: desktop platform, mobile platform and web platform. The first two possibilities require paying a license in order to access to them, while the web platform is accessible for free.

3.1.1. Model viewer

Once in the web version, it is possible to select the files that we want to see and open them in the platform viewer. The platform offers two viewer possibilities: the current viewer and the beta viewer. When selecting any of them, the selected models are shown. While in the first viewer the IFC model tree is displayed, in the beta version this function is not available, but it is possible to add other files from it. It is also remarkable that in the current viewer it is possible to filter the shown element by their IFC class, whereas the areal selection is not allowed. The author concluded that there is not a best viewer, it just depends on what is required to do, and the tools needed to obtain it. By the way, the graphics displayed on the beta version are better.

Both viewers allow making comments, draft, and save the views. Additionally, it is possible to assign a task to this view, which is very useful to make the responsible group user know when it is necessary to make changes to the model. The list of tasks is visible in the "TODO" tab, but only those referred to the user or group are visible for the simple user. Only the administrator can see all the assigned tasks. The comparison between both viewers is summed up in the following table:

Viewer version	Current	Beta
IFC Tree	Yes	No
Add files once opened	No	Yes
Filter	By IfcClass	Not possible
Areal Selection	Not Available	Available
Remark	Yes	Yes

"ToDo" assignment	Yes	Yes
Comment	Yes	Yes
Save views	Yes	Yes
Clash detection	Yes	Yes

Figure 51 - Comparison table between Trimble Connect's viewers.

The up-left window of the viewer presents the loaded models, structured as a tree, like it was explained in the IFC export paragraph. It also allows the user to turn on or off the objects by clicking in the eye symbol.

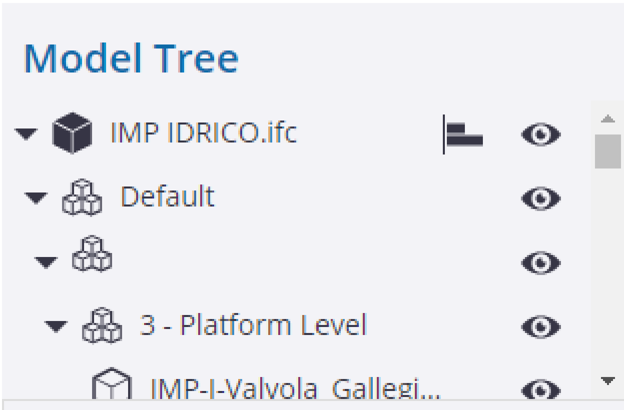


Figure 52 - IFC model tree in the current viewer.

There is also an Activity tab where all changes and events from the platform are listed. It works like the "archive" section explained into the Common Data Environment section. Trimble Connect allows to filter activities by type and group or user involved. From there it is also possible to access to the model viewer, if there was any change in a model, so the necessary corrections can be made.

3.1.2. Clash detection

Clash detection is the function that allows the modeller to realize when two different objects share the same coordinates in the model space. This happens frequently, especially in collaborative environments where many people upload models and constantly make changes. The BIM manager is the person that must be alert when clashes take place and advise the affected user which changes must do, once again, through the "ToDos" assignment.

This powerful tool is included in both model viewer versions, unfortunately it takes many minutes to effectively show the report. Nevertheless, it is understandable for a software that works as a cloud-based platform to take much time in verifying the overlapping of thousands of elements online. If the BIM user wants a more quickly response, this clash reporting can be made in other offline software, like Revit for example.

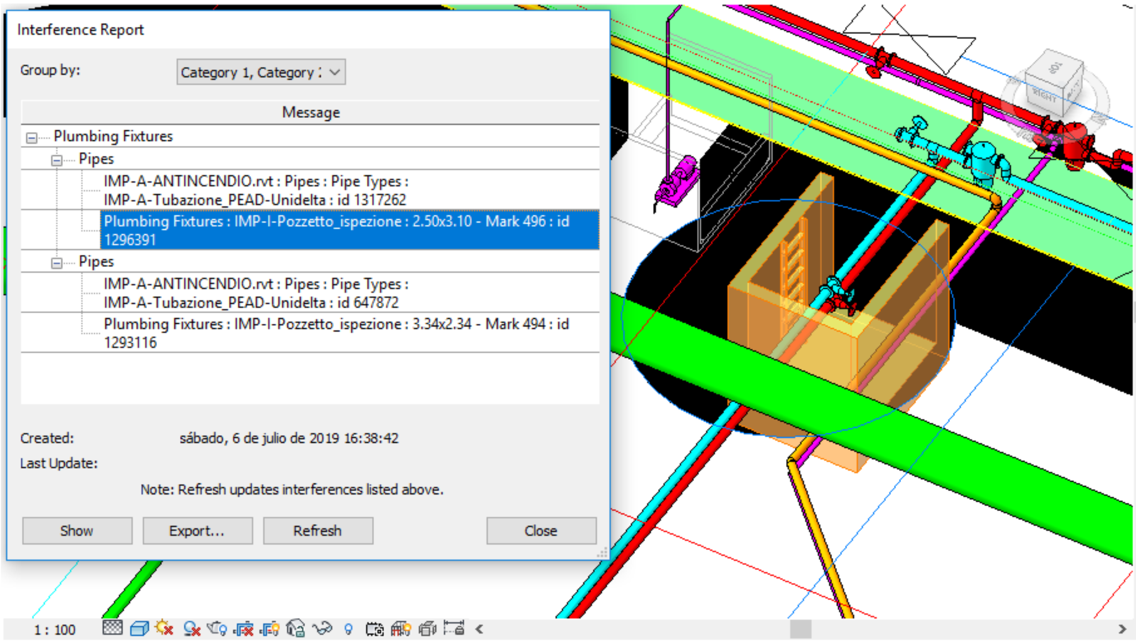


Figure 53 - Revit clash report.

In this last case, the models necessarily must be downloaded and saved into the computer local disc. So, for checking clashes between the MEP models the Revit tool was used, while in the case of the clash detection between the MEP models and models corresponding to another discipline, the Trimble Connect Tool.

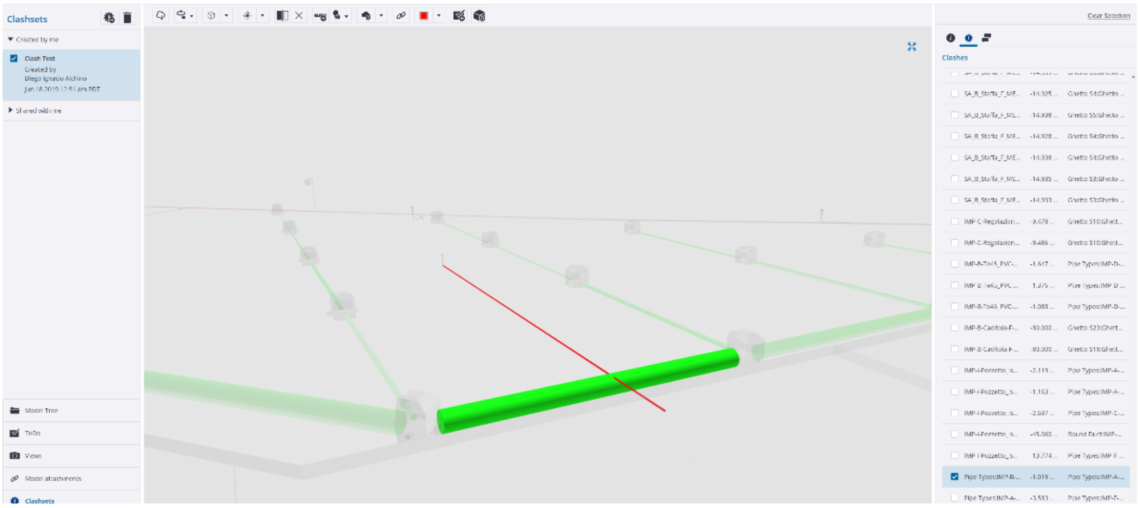


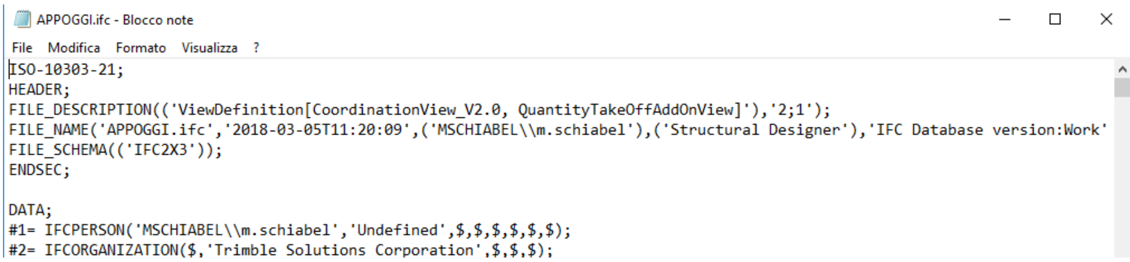
Figure 54 - Trimble Connect clash detection.

3.2. Exporting Process

Revit 2019 includes the possibility of exporting models to IFC format, but before doing that, it is necessary to set up the configuration. To set up the equivalences between Revit and IFC model is usually called "mapping". In this thesis two different class mapping were done: the class mapping and the data mapping. They are both explained in the following paragraphs.

The IFC format has been designed to produce all the building's information, along its whole life-cycle. It includes from feasibility analysis to its maintenance and final demolition. Industry Foundation Class is an open and standard data model, whose objective is to make interoperability in the architecture, engineering and construction (AEC) industry easier. It is the most used collaboration format in BIM projects, being supported by near 150 software applications worldwide (McPartland, 2017). It is defined by its creator, buildingSMART®, as "the complete and fully stable open and international standard for exchanging BIM data".

An IFC file is composed by two parts: the header and the body. While the header contains general information about the building model, the IFC version and software used, the schema, and the MVD, the body contains the information about the geometry and attributes of the building itself.


APPOGGI.ifc - Blocco note

File Modifica Formato Visualizza ?

```
ISO-10303-21;
HEADER;
FILE_DESCRIPTION(('ViewDefinition[CoordinationView_V2.0, QuantityTakeOffAddOnView]'),'2;1');
FILE_NAME('APPOGGI.ifc','2018-03-05T11:20:09',('MSCHIABEL\\m.schiabel'),('Structural Designer'),'IFC Database version:Work'
FILE_SCHEMA(('IFC2X3'));
ENDSEC;

DATA;
#1= IFCPERSON('MSCHIABEL\\m.schiabel','Undefined',$,$,$,$,$,$);
#2= IFCORGANIZATION($,'Trimble Solutions Corporation',$,$,$);
```

Figure 55 - IFC format file's header, opened in Notepad.

Every IFC model is formed by entities, each one defined by the IfcRoot entity. Three types of entities exist as well: objects, relations and properties. They form the second level of specialization within the IFC class hierarchy. Objects are the generalization of any semantically treated thing and they can be related thanks to relationships (BuildingSMART, 2016). Relationships are also used to assign property sets to a certain object, which defines all dynamically extensible properties.

IFC extension models have their own structure, which can be represented as a tree. Each element is necessarily related to other objects that take part on a hierarchical sequence presented below.

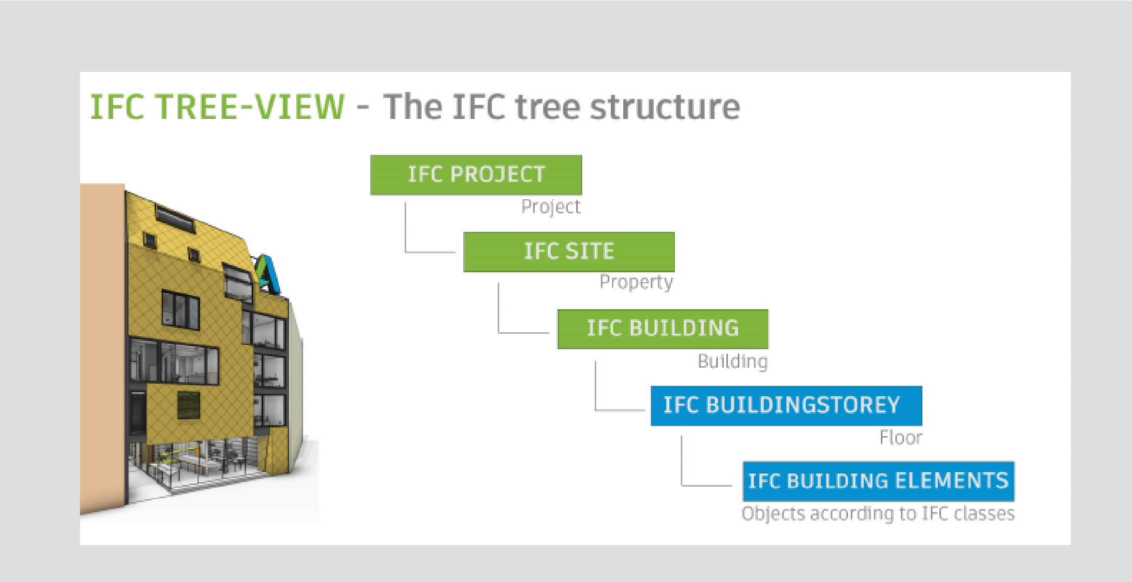


Figure 56 - IFC format file's structure and its equivalence with Revit Software entities.

Model View Definition (MVD)

It determines how an IFC file is used, because it enables a specific data exchange scenario. MVDs are used for targeted exchange of specialized models, considering the graphic and content-related information that the planner needs. Thanks to MVD, the designer can specify what information needs to be transferred, when and by whom. BuildingSMART webpage defines it as a subset of the IFC schema that is needed to satisfy one or many Exchange Requirements of the AEC industry (BuildingSMART, 2016).

Revit Model View Definitions available by default start with a term such as "IFC2x3" or "IFC4". They represent the data organizational structure and their identification tag, and its number indicates the data structure version. 2x3 version is the most popular, but it has some limitations. IFC4 is the most actual one, it extends the geometric parametric support, materials and structure management. IFC5 is going to be the next release, it is currently in planning phase (CadLinesw.com).

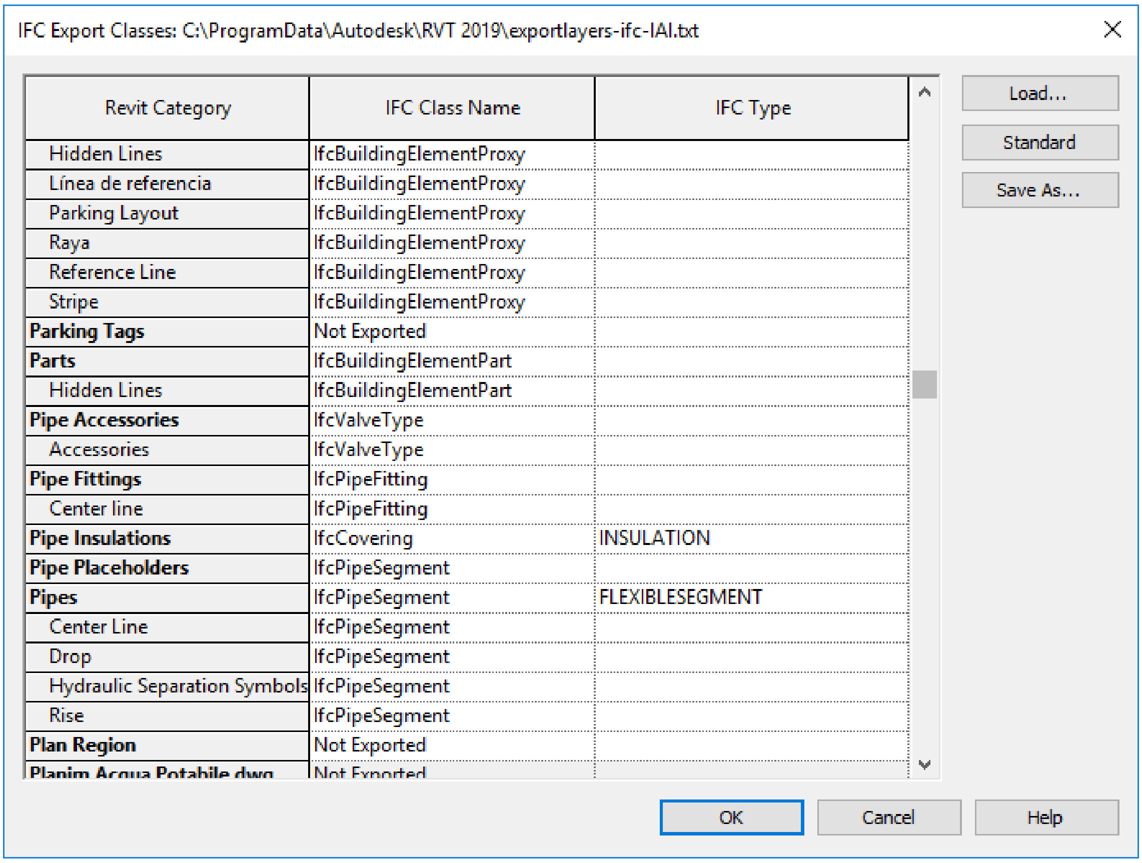
Apart from the version, some MVDs are created for following national standard requirements such as IFC2x3 COBie 2.4 Design Deliverable, that follows BS 1190 standards.

3.2.1. Class mapping

As it was already mentioned, Revit families are part of a bigger group called categories. The equivalent to Revit Categories in an IFC file is called "class". This class is represented into the IFC schema as IfcClass. It is important to pick the correct IfcClass for each element in Revit, because according to the selected class a certain property set will be assigned to those elements. A property set is a group of properties that are inherent to a certain type of object. Just to be clear, the properties that defines a certain door are different from those common to a floor.

There is a list of available IFC classes according to the IFC specification used. The next step is to define into which IFC class will be exported our Revit categories. This is defined thanks to a TXT extension file known as "mapping file" accessible from the Revit IFC export options. By default, Revit has a significantly accurate mapping file. However, sometimes making some adjustments is needed.

The mapping file is a TXT file that can be opened as a spreadsheet in a software such as Microsoft Excel. The file contains three columns, the first one indicates the name of the Revit Category, while the other two indicate to which IFC class and IFC type the category must be exported.



Revit Category	IFC Class Name	IFC Type
Hidden Lines	IfcBuildingElementProxy	
Línea de referencia	IfcBuildingElementProxy	
Parking Layout	IfcBuildingElementProxy	
Raya	IfcBuildingElementProxy	
Reference Line	IfcBuildingElementProxy	
Stripe	IfcBuildingElementProxy	
Parking Tags	Not Exported	
Parts	IfcBuildingElementPart	
Hidden Lines	IfcBuildingElementPart	
Pipe Accessories	IfcValveType	
Accessories	IfcValveType	
Pipe Fittings	IfcPipeFitting	
Center line	IfcPipeFitting	
Pipe Insulations	IfcCovering	INSULATION
Pipe Placeholders	IfcPipeSegment	
Pipes	IfcPipeSegment	FLEXIBLESEGMENT
Center Line	IfcPipeSegment	
Drop	IfcPipeSegment	
Hydraulic Separation Symbols	IfcPipeSegment	
Rise	IfcPipeSegment	
Plan Region	Not Exported	
Planim Acqua Potabile dwg	Not Exported	

Figure 57 - Revit Mapping file.

During the exporting process, a particular problem appeared when trying to export the Mechanical Equipment Revit Category. By default, it is exported as a Proxy element, what does not represent the reality. The problem was that the category does not match any existent IFC Class Name, so mapping files were not be a solution. In fact, IFC Classes are more specific, since there are more than one class that can be tagged as a mechanical equipment. The problem was specific to these elements:

Element	Revit Category	IfcClass
Fire hydrants	Mechanical Equipment	IfcFlowTerminal
Pumps	Mechanical Equipment	IfcFlowMovingDevice
Filters	Mechanical Equipment	IfcFlowTreatmentDevice

Figure 58 - Mechanical equipment families and its IFC equivalences.

The list of IFC classes was taken from the IFC specification for 2x3 Coordination view MVD on buildingSMART webpage. In the webpage there is a graph where the architecture of the IFC version is represented. On the top, some circles where different domains are shown, by clicking the one that is required (IfcPlumbingFireProtectionDomain or HVACDomain) the IfcEntities specific to that domain are shown.

Figure 59 - IFC2x3 version domains

Once it was decided to which class the mechanical equipment families will be mapped, the next step was to research how to specify the export setting in Revit. The existence of "IFC Parameters" was found in the Autodesk guides. These parameters, called "IfcExportAs" and "IfcExportType", allow to do the class mapping by family types. They should be saved in the shared parameters TXT file, by selecting "text" option as the type of data. The last step is to modify the families using the family editor, enter in the family parameters and add both IFC parameters to the family as "type parameter".

The filling of these parameters value can be made in the family editor or inside the project, by clicking the object and then selecting "Modify Type".

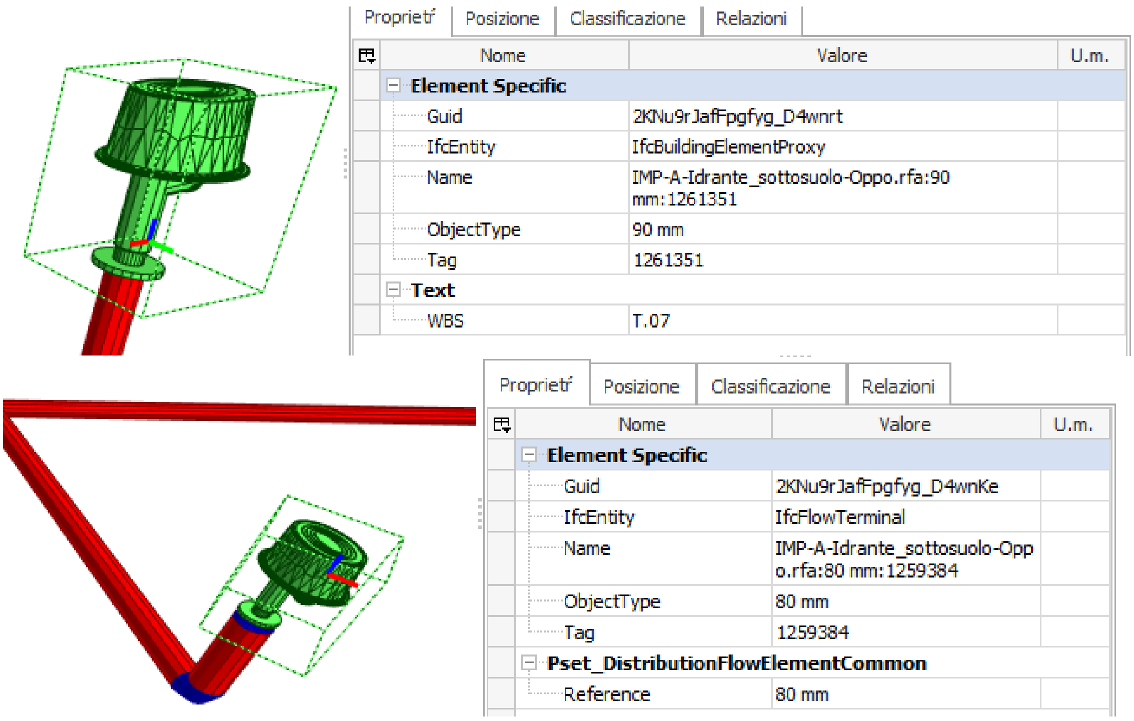


Figure 60 - Before and after an appropriate Class Mapping process.

3.2.2. Data mapping

By controlling the data mapping the modeller makes sure that information goes to the correct position. There are some standard IFC Exporter parameters, such as IfcName, IfcLongName, IfcObjectType and IfcDescription that can be overridden in order to follow the standard and to avoid creating several parameters inside the IFC file. However, when looking into the company's IFC models, this technique has not been followed, so for the purpose of this thesis the author decided not to follow it either. Using representing parameters names in spite of generic names was preferred.

The way parameters are exported is defined in the IFC export tool in Revit. The first dialog box asks the customer to choose an MVD. Then the possibility of customizing the MVD is given. The Model Viewer Definition used for accomplishing the goal was a duplication of the **2x3 Coordination View 2.0**, since it is the most widely used and supported IFC version. However, it is necessary to make some changes to it in order to do the data mapping. For doing this it was necessary to create a duplicate of the MVD, since Revit does not allow to change the setting on default MVDs.

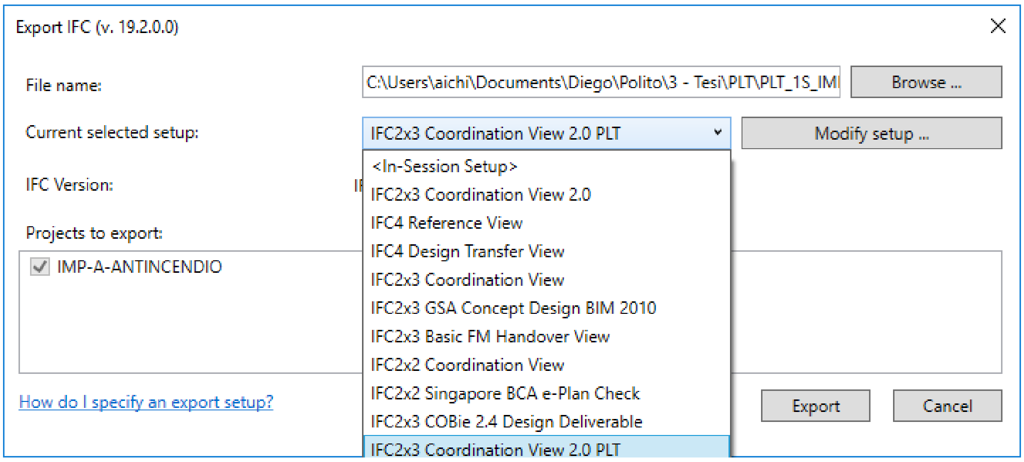


Figure 61 - IFC Exporting Revit setup

By default, the option "Exporting IFC common property sets" is checked. This option maps all Revit properties identified by the MVD that follow certain rules and match them to the correct attribute name in the IFC property set. However, some parameters do not follow the IFC naming standard, so they will not be exported, being lost in the process.

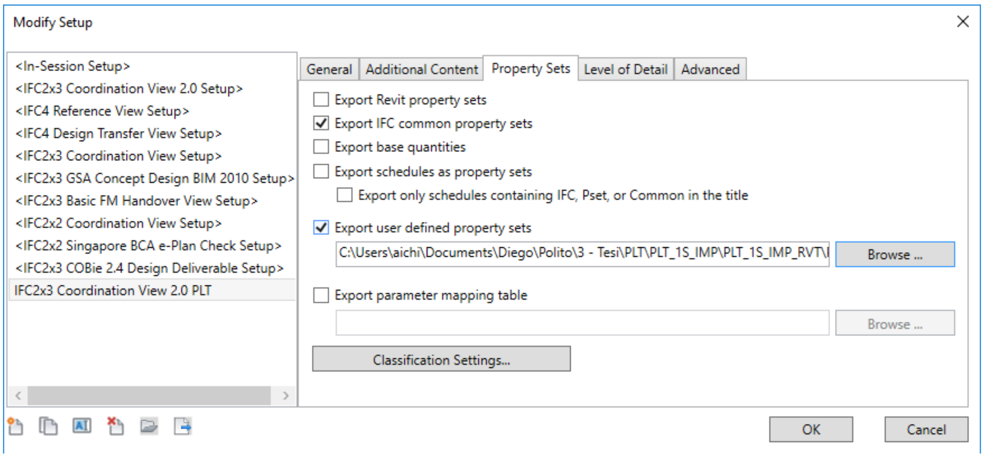


Figure 62 - Revit MVD customization, data mapping.

Export Revit Property sets allow to export all properties and parameters in the file. Despite being a fast and easy solution, the use of this option may result in duplicated information, making the file heavier than necessary. The use of schedules also incurs to this issue.

The author strongly recommends the use of user defined property sets for doing the export. This consist in a TXT file that must be structured following certain rules. They allow the user to map each parameter in Revit and pick the property set at which will belong and the name that will show in the IFC file. The TXT file is structured as follows:

PLT-MappingParam(FULL).txt - Blocco note

File Modifica Formato Visualizza ?

```
PropertySet:    Classificazione T       IfcElementType
UniClass 2015   Text    Uniclass 2015
OmniClass 2015  Text    OmniClass 2015
Masterformat 2014       Text    Masterformat Code
Uniformat 2010  Text    Uniformat Code
UNI 8290-1 1971 Text    UNI-8290
PropertySet:    Scheduling      I       IfcElement
WBS     Text    WBS
Data Istallazione       Text    Install Date
Giorno Istallazione     Integer Install Day
PropertySet:    Manutenzione    I       IfcElement
Data Sostituzione       Text    Replacement Date
Giorno Sostituzione     Integer Replacement Day
Propertyset:    Manutenzione    T       IfcElementType
Elemento Manutenibile   Text    Elemento Manutenibile
Responsabile    Text    Management Responsible
Frequenza Controlli     Integer CtrlFreqDays
Frequenza Sostituzioni  Integer ReplaceFreqYears
```

Figure 63 - User Predefined Data Mapping file.

At first, creating a TXT file may look as a last resource option. It is easy to make mistakes and it requires to know something about IFC version structure. However, once the user gets the idea of how it works, it results very advantageous since he can decide how and where to map each parameter. One more detail is that by using this option from the federated model, no problems took place, since the Revit option did not work for exporting linked files.

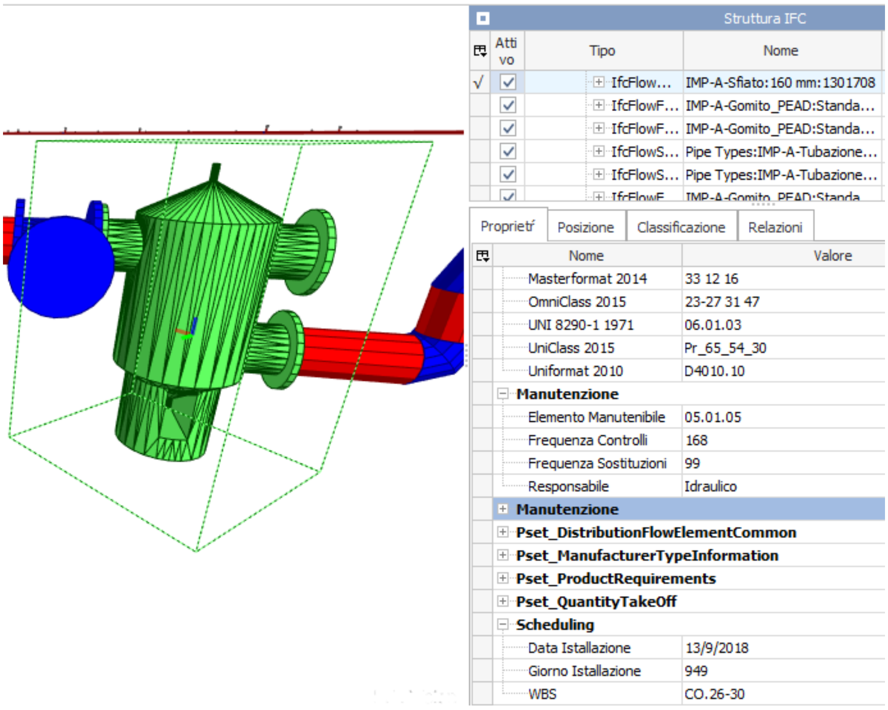


Figure 64 - IFC Export result.

3.2.3. Materials

Another issue that appeared during the exporting process was the absence of colours in the objects. Despite of being included into the piping system properties and being displayed on Revit, when the IFC model was loaded into Trimble connect the element appeared as white.

So instead of selecting the display colour in the system properties, it was decided to change the material colours. For this reason, a new material for each system was created, as it can be seen in the following picture.

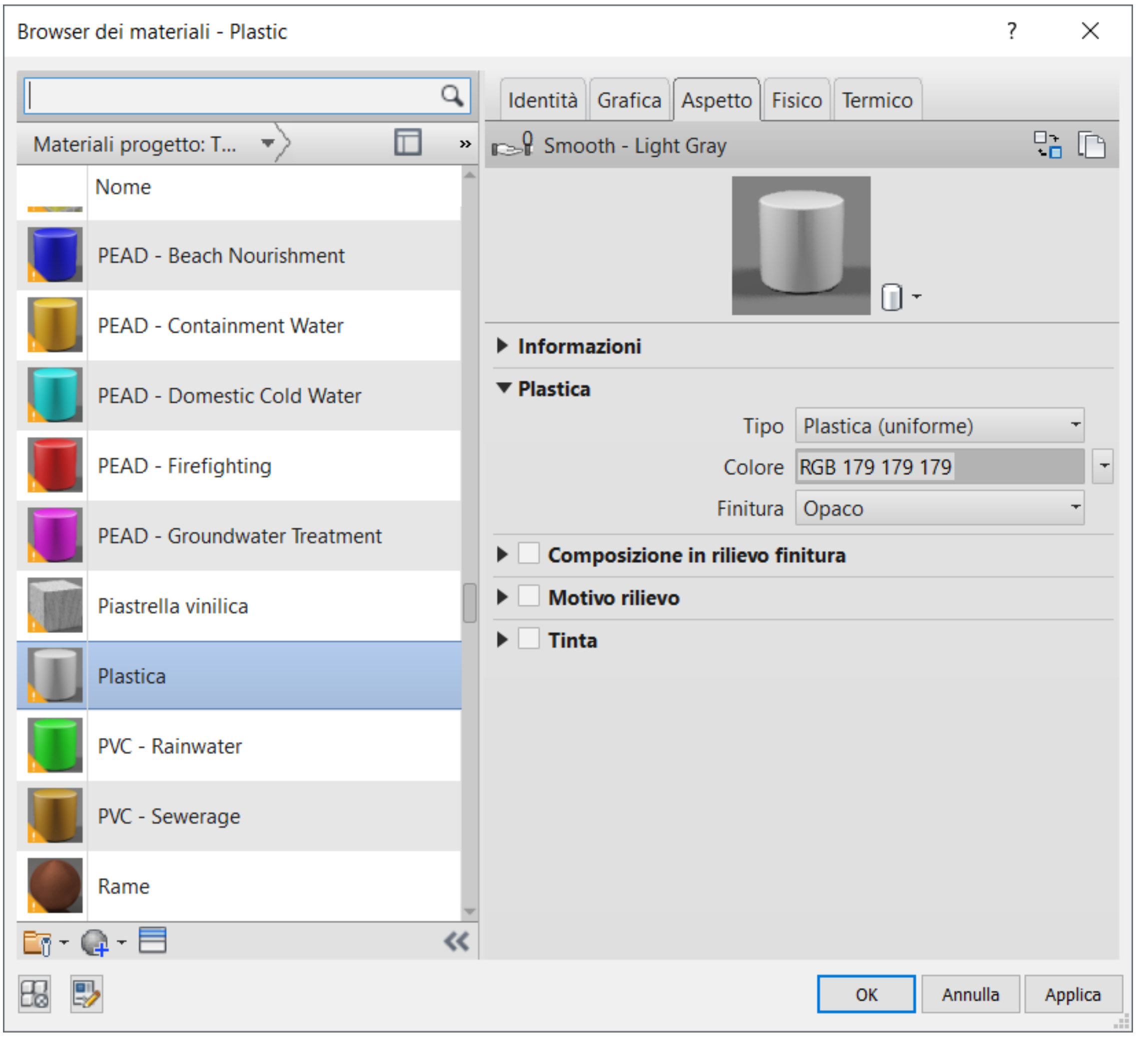


Figure 65 - Revit material library.

Nevertheless, this is not the best practice, since the real material is not displayed in case of realistic views. But as the aim of this project is to highlight the different systems in the model, this solution meets the requirement. It must be remarked that this solution is only applied to the pipe elements. It seems like they are the only elements where material is exported, while the fittings remain in white colour.

4. Model Applications

As it was explained in the first chapter of this thesis, the creation of a model may have different purposes. While the ones provided by the designer company were probably created for the scope of calculating materials or costs, the scope of the models created by the author where decided to be used in another way. Depending on the model's scope the number of elements and the level of detail will change.

For the purpose of this thesis, two different objectives where tried to follow. First, it was made a 4D simulation about how the construction process was done. Furthermore, an analysis studying the difference between what was predicted and what really occurred was made. In project management this process is known as task following. However, to be considered as a project management activity, it must be considered the cost factor. The inclusion of costs would have required more information that the available. Otherwise, the only models the author was able to edit or include cost parameters were the ones related to the equipment, which summed up is not even a 10% of the compressive building cost.

Lastly, data obtained from the model and from the simulation was employed to start a facility management approach, useful for the operational phase activities. First, the maintenance plan was linked to the model by assigning to each element the correspondent code. Once it is identified, with the information about the installation day obtained in the 4D analysis it is possible to manage every asset in the workplace that requires to be maintained. The first idea was to use a BIM-based Computerized Maintenance Management System, then in a database software like Microsoft Access.

4.1. 4D Analysis

As it was mentioned in the introduction of this thesis, a four-dimension analysis consists on the inclusion of a parameter that considers time factor. The parameter that was assigned to all instances present in the models was called “WBS”.

The 4D analysis made during this thesis was for the construction phase, so in order to make the analysis it is necessary to work with the Project Information Model.

Work Breakdown Structure

It is defined as a deliverable oriented hierarchical decomposition of the work to be executed by the project team. There are some rules that must be followed in the process of creating a WBS (Lee, 2018):

The 100% rule says that the WBS must include 100% of the work defined by the project scope and captures all deliverables in terms of the work to be completed, including project management.

WBS structure must be mutually exclusive. This means that it must not exist overlapping in scope definition between different elements of the WBS. An ambiguity could result in duplicated work or miscommunications about responsibility and authority, so special attention has been paid to this concept.

A WBS is made of outcomes and deliverables. They are the only elements that must appear on it. Inclusion of actions must be prevented, focus must be made in the elements produced more than in the movement parts that made it possible.

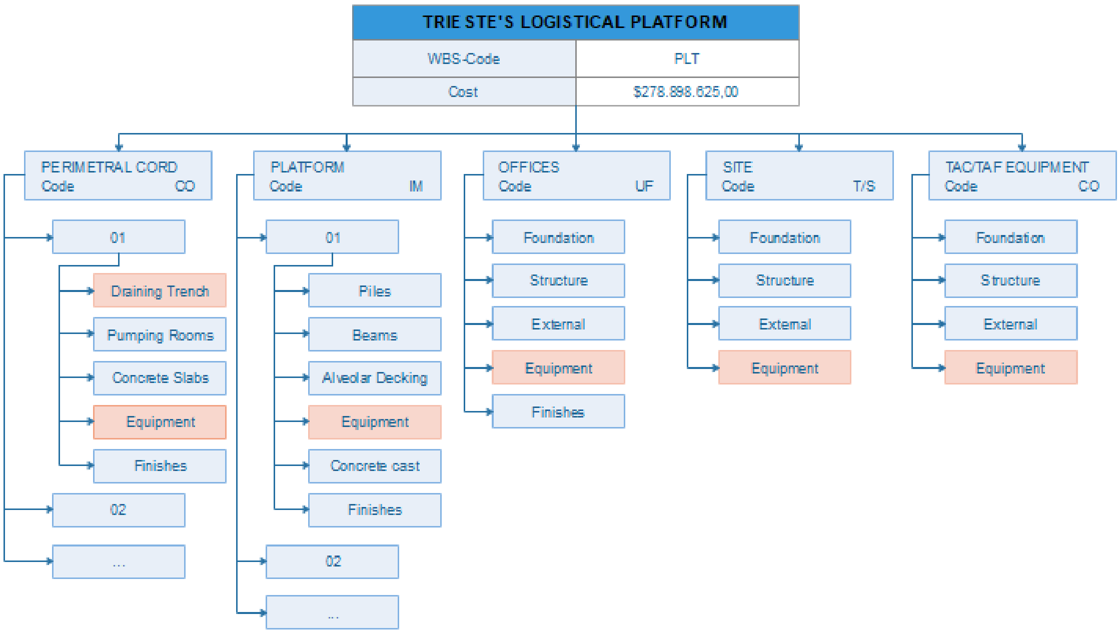


Figure 66 - Work Breakdown Structure of PLT project.

The 8/80 rule establishes that work packages must take between 8 and 80 hours of effort (1 to 10 days of work). This makes an idea of the level of detail developed in the creation of the schedule. So, for example, if a work packages production takes more than 10 days of work, it must be divided into other different work packages with a shorter duration.

4.1.1 Scheduling

A schedule is a usual concept in the construction management field. It is defined as a time, cost and resource control and management tool that identify activities for entire project with time scales, required budget and resources, and relations with dependencies. The Schedule is a list of planned activities to be done within the allowed time frame. It serves as a tool to assist project management in achieving project goals through efficient use of available resources (TheProjectDefinition).

The project schedule must be created to introduce time dimension and to get a 4D model. Unfortunately, the original schedule of the construction company was not shared with the author, but he decided to try elaborating an approximative schedule, so the time dimension can be assigned to his model.

The rest of the information about the timetables were taken from the reports. Some clues are described below:

- Initially the estimative duration of the entire project was 852 consecutive days, equivalent to 30 months.
- After realizing that some excavation works had taken more time than expected, the approved heritage study indicated that the expected finish date changes from 09/06/2018 to 29/01/2019. However, some activities had to be finished before finishing November 2018, as they were linked to European contribute.
- During the process of land reclamation, there were found materials containing asbestos with a crumbly consistence. This fact has stopped the activities, while a bureaucratic process began: a meeting was called where a permanent securing of the place (Messa In Sicurezza Permanente – MISP) was installed. The material was found on 13/09/2016, while activities restarted on 12/12/2016.
- By phone call, the company employee told the author that the number indicated on each desk of the structure corresponds to the order on concrete jetting sequence.
- An old worksite report provided a rough description about the different phases adopted to do the work.
- Previous knowledge about the thematic allowed to suppose an approximative productivity of the resources employed. A duration of one day for pile was considered, while the productivity of the excavator considered as 10 m3/day.

Microsoft Project software was chosen for creating the schedule. The reason why it was selected was its availability and the prestigious that Microsoft firm has. Luckily an educational was provided by the university.

Microsoft project’s is a tool principally used for the project management. Its scheduling tools allows the user to create tasks, make a relation between them and create a Gantt diagram in an easy way. For doing this the first step was to create a calendar, where workable days and hours were inserted. It was considered a 24 hours calendar, with the creation of non-workable days during the process of securing the place.

The way the software relates the different tasks is by creating links, which can be from different types: Finish to start, Finish to start, Start to Finish and Start to start. The possibility of assigning resources to each task is also provided, however, it was decided to use the software just for the scheduling

For this thesis only Finish to Start links were created. WBS principles were adopted. A first schedule approximation was made considering groups of piles, groups of beams and alveolar panels and concrete decks as different work packages. Although it was still an approximation, when trying to import the schedule into Synchro an error message alerted that maximum number of tasks allowed was achieved. For this reason, the final schedule consisted of less than 125 tasks. It was decided to adopt the zone division as the deliverables associated to the different tasks.

This resulting schedule shows a WBS structure that does not meet the requirements of the 8/80 rule, because some tasks duration was too long. Nevertheless, for the purpose of this thesis, the simplified schedule was enough to introduce the 4D concept and analyse the interoperability between two different BIM software tools.

Tasks list and the Gantt chart, which is the graphical representation, are shown in the Annex 2 section of this thesis.

4.1.2. Syncro PRO Software

Synchro PRO is a 4D BIM/VDC construction scheduling and project management software. This tool allows matching a BIM model to a schedule in order to update the construction plan in 4D in a matter of minutes (Syncro Software).

The software was created by Bentley®, another well-known company in the BIM industry. This may be a problem in terms of interoperability, since our project has been modelled in Revit. During this thesis, two different approaches were made in the integration of both software:

- Exporting/importing directly from Revit thanks to an add-in deliberately created
- Using IFC files.

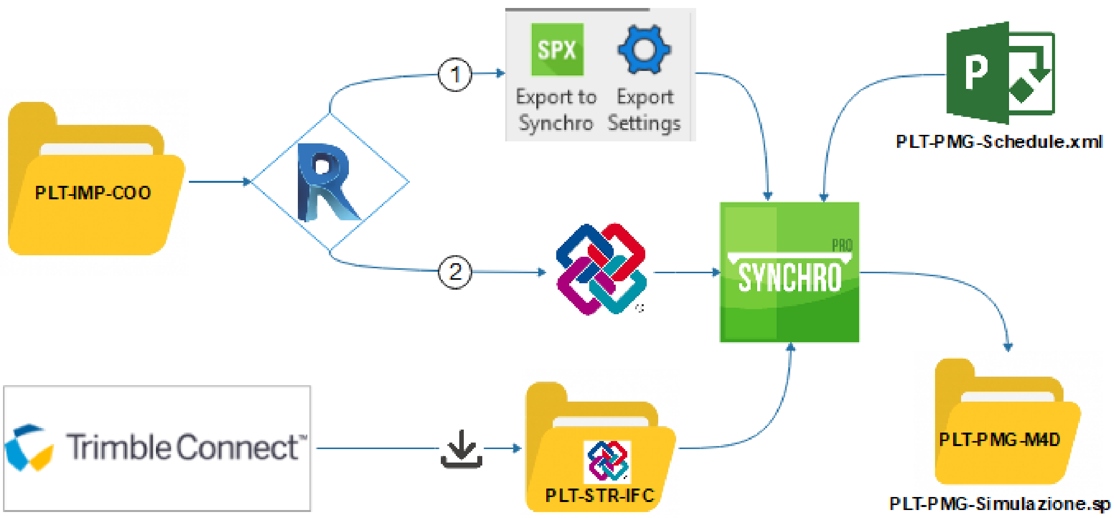


Figure 67 - 4D Analysis workflow.

Synchro initial layout consists of five windows. In the left it is the navigator, where is possible to see useful components like resources, 3D objects, project, animations. Two windows show the schedule of tasks and the Gantt chart, under them the 3D viewer of the model is placed. The last window, at the right edge, is where properties are shown.

Revit plug-in

The Revit add-in tool of Synchro allows the user to make some changes in the export settings, like the parameters to be exported. The objective of this exported model is to be linked to a schedule, so every parameter that has nothing to do with timetables or costs would be considered as useless. In this case, the shared parameters related to the maintenance and element classification were excluded from the user fields list.

A detail that saved considerable time in the exporting process was that the plug-in allows to export also linked files, so the SP export has been made from the coordination model. The result of the exportation process is a file with SP extension, readable in all Synchro software tools.

The import of the SP file is done by going to File > Import > Synchro project. Once the SP file exported from Revit is chosen, a new window appears asking which elements and parameters are desired to import. In this case everything has been exported, since the parameter filtering was made previously in the Exporting options.

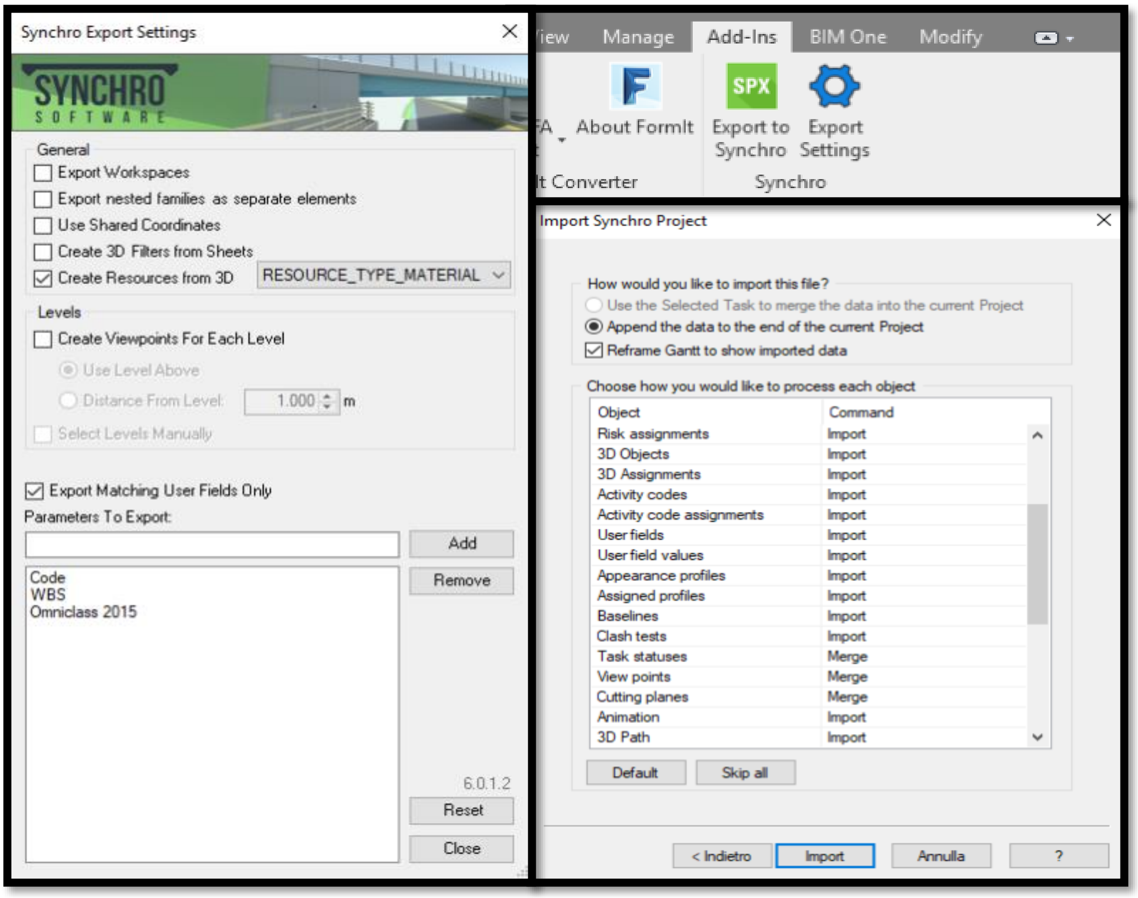


Figure 41 - Synchro export and import settings. In the left, export settings from the Revit add-in. In the top-right, position of the Synchro plug-in in Revit. In the bottom-right, importing SP file options, once in Synchro software.

IFC Importing

A special mention will be done to the IFC export options used for the 4D simulation. As many models were going to be imported into the simulation, it was decided to reduce file sizes. This would be the equivalent to choose the parameters desired to export from the Revit Add-in.

The way of doing this is to change the set up in the property set settings into the export IFC settings. This time, the user defined property sets was reduced in order to get just what was necessary: the WBS parameter.

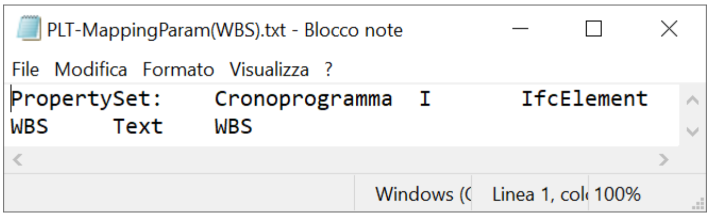


Figure 68 - TXT file for importing WBS parameter.

Schedules

Synchro pro gives all the necessary tools in order to create an own schedule from scratch, similar to MP ones. Since this schedule was already created in MS Project, the import schedule option was selected. For doing this, the schedule must be saved as an Extensive Markup Language format file. Hopefully, Microsoft Project allows to save schedules with this format. XML is a language for structured data interchange. It is used to create common information formats which can be shared wherever ASCII standards are followed, like web pages (Rouse, 2010).

Synchro Contains

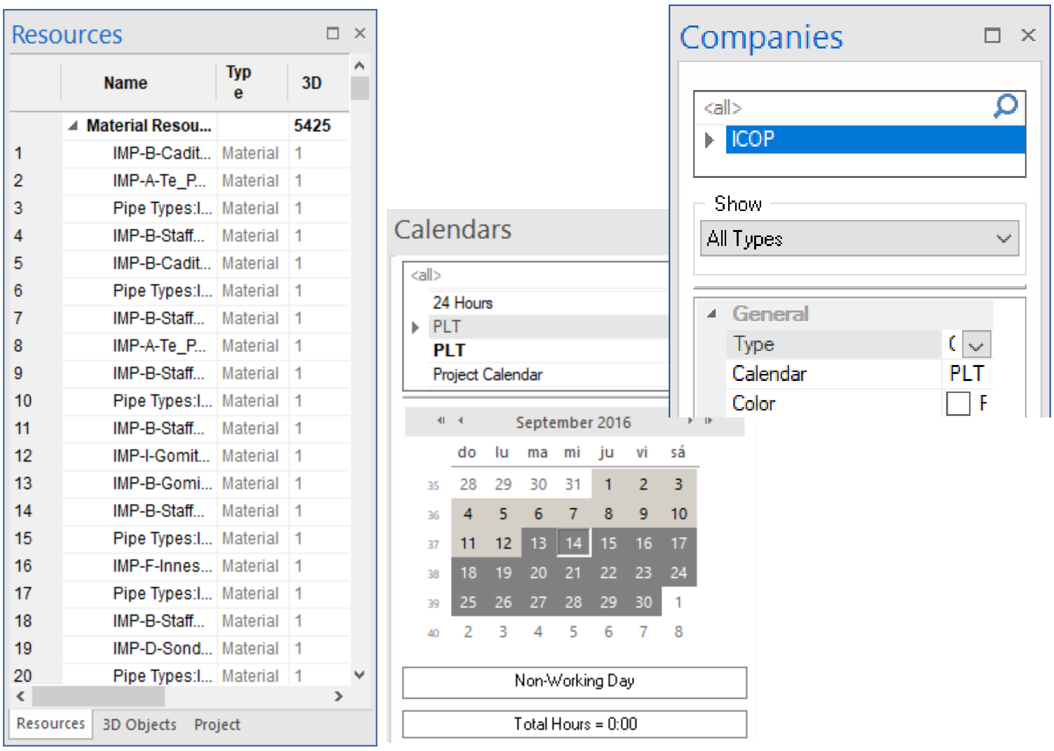


Figure 69 - Synchro resources, calendars and companies navigator.

Importing the Revit model creates not only new 3D objects in the project, but also the material resources. Resources belongs to one of the four different types: Human, Equipment, Material and Location.

Resources belongs to companies, so if no company was yet created, new resources will be assigned to a no-name new company. The name of this unnamed company was changed to ICOP.

Next step was to assign the new resources to the different tasks. It is unthinkable to select one by one thousands of elements and assign each one to a task. Consequently, auto-assignment tool must be employed. For doing this, the key is to have planned the parameter that will indicate to which task will the resource be assigned. The code employed for this aim was “WBS”.

The auto-assigning rule requires the task field value that will be joined with the WBS parameter. The user field named “Resources code” was added on the schedule. This is made by left clicking on the task list and selecting the Customize Columns option. Once the assignment is done, it is possible to move the red spotted line that represents the “focus time”.

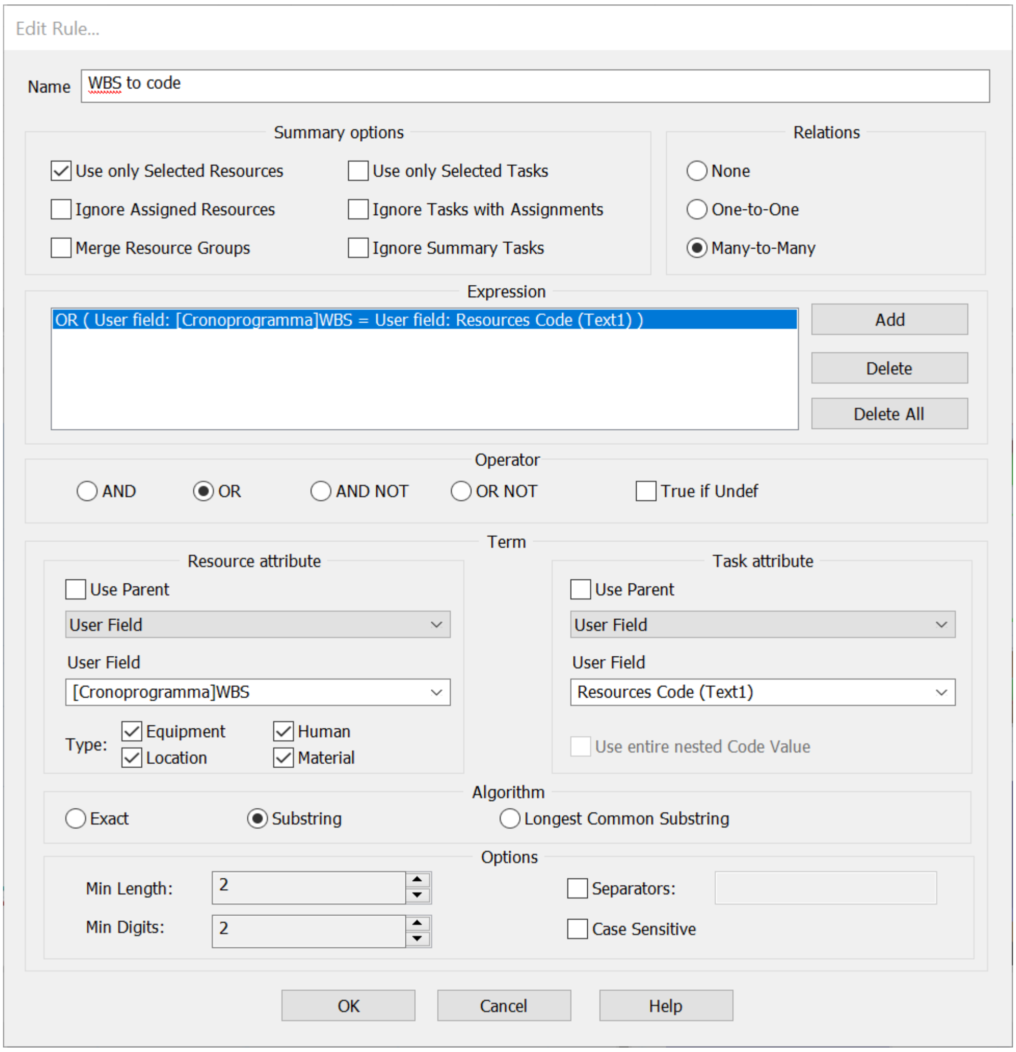


Figure 70 - Synchro auto-assigning tool.

Task progress tracking

An interesting concept that the author decided to add to the 4D model was the comparison between the planned schedule and what actually happened. This activity is called as "progress tracking" in the project management environment. The project manager is responsible for daily evaluating the project progress, in order to have information about how the schedule is being followed and evaluating the decisions to be made regarding to economic financing.

For the purpose of this thesis costs factor was not taken into account, however, the author wanted to mention Synchro potentiality. The task progress tracking was done taking as a reference satellite images taken from Google Earth. Although it is not the correct way to perform project management activities, the idea of doing this was to try the tools provided by the software.

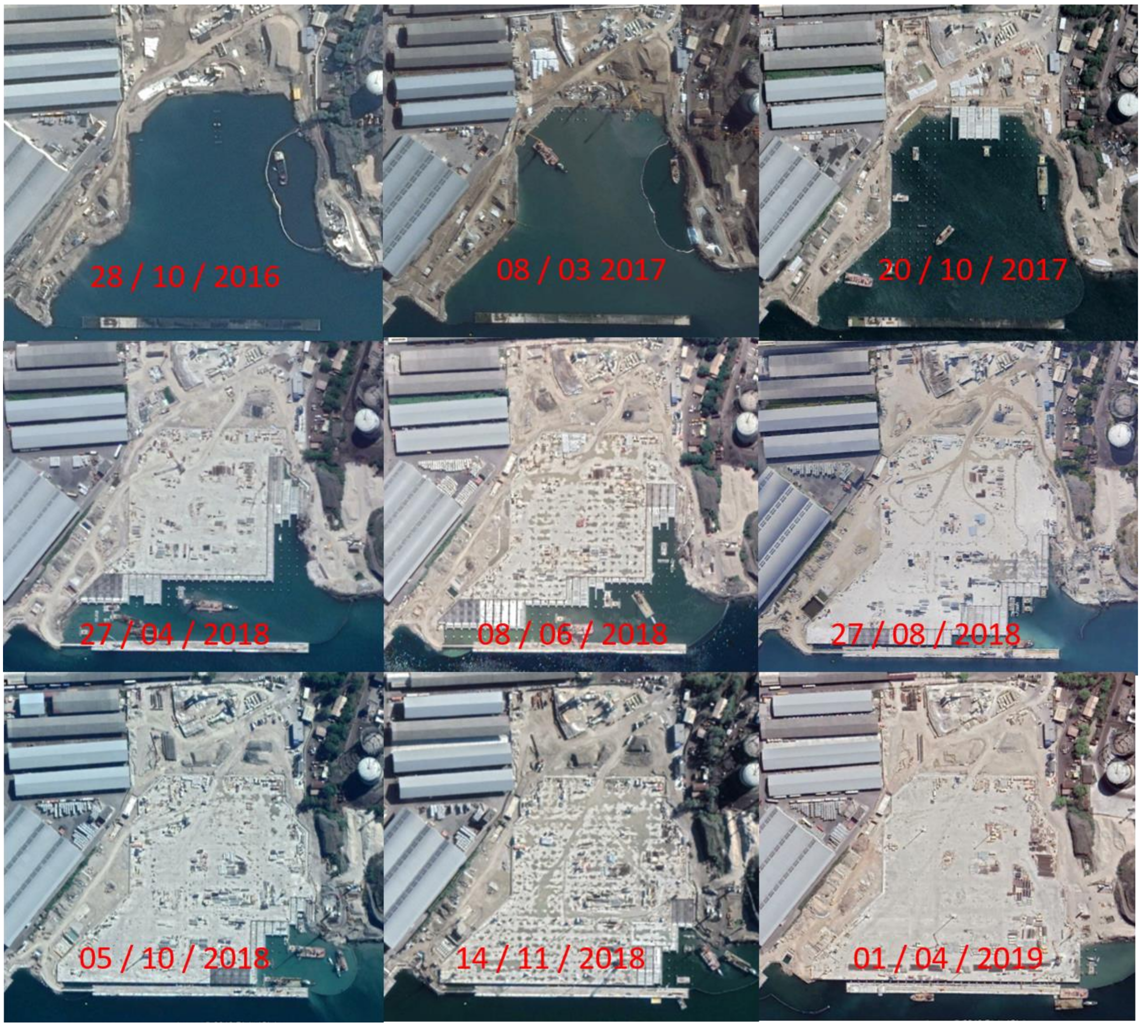


Figure 71 - Evolution of the worksite showed on satellite images.

First it is necessary to create a baseline that copies the schedule form. A baseline is the value or condition against which all future measurements will be compared. Synchro allows to maintain a baseline schedule and track revisions to it. Controlling the baseline is essential for the project success. Once the baseline is created on Synchro, it is possible to follow the project process. The baseline is created by selecting all tasks user wants to be in the baseline (or doing Ctrl+A), left clicking and choosing the “Baseline Selected Tasks” option.

The task tracking is done by using a reference date from which the analysis is made. This reference day is named on Synchro as “Data date”, and it can be set up from the Project tab inside the navigator. By default, it is selected as automatic, which means that Synchro will use the actual date as the data date. The data date is represented in the Gantt chart by the dotted blue line.

Changing the tasks status can be done by left clicking on each task and selecting the “progress” option or changing its status into the task properties panel. There are five different ways to do the task tracking on synchro: Automatic, Duration, Manual, Physical and Units. This can be changed for each task going into its properties. The automatic progress type was left, as the default, since the other options may require further information like a physical measurement about the task progress or other resources like human and equipment, which was not available. Automatic progress type means that when the task status is updated, if the start or finish date is selected, the progress percentage is automatically calculated.

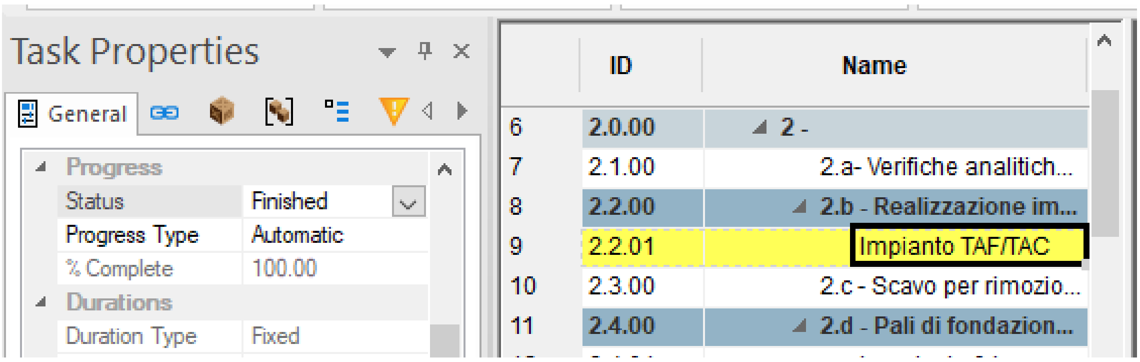


Figure 72 - Synchro, changing tasks status from its properties.

The task progress of all tasks was changed to “finished”, choosing the start and finish dates according to which the images show. By doing this, new information about the tasks is attached: the actual start date and actual finish date. The following step is to update the schedule with the actual dates, so the Gantt chart will show the baseline created first, while the actual schedule is displayed.

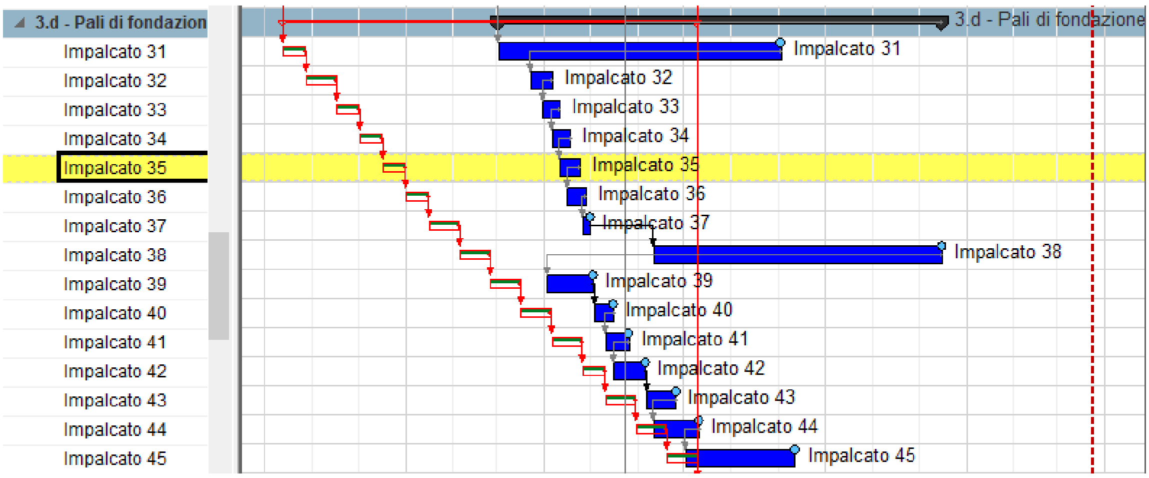


Figure 73 - Gantt chart of the baseline, in red, and the actual schedule in blue.

The way to represent this is with the 3D windows. It is possible to open more than one, in order to assign the baseline to a window and the actual schedule to the other one.

By changing the appearance profiles, it can be customized the way resources appear in the 3D viewer. As is was picked the install option, objects that are going to be installed after the focus time will not appear. Other possible options provided are maintain, remove or temporary. By moving the focus date (easily done by dragging the red spotted line in the Gantt chart), it is possible to see how 3D objects appear and disappear from the 3D viewer.

4.2. Asset and Facility management

Asset and facility management are activities developed during the operational face of the building. Operational lifetime of a building is estimated to be the most expensive period of the building's entire life cycle, and this is the fundamental reason why BIM models tends to be used during this phase.

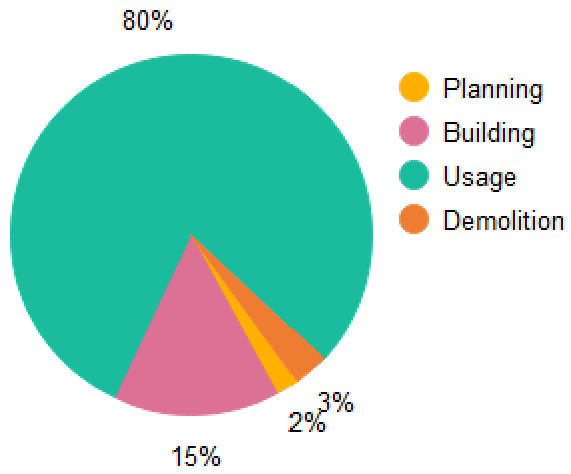


Figure 74 - Life-cycle costing (Statista, s.f.).

First, the author would like to remark the difference between two concepts that seem similar but have important differences. (Kavrakov, 2015):

	Asset Management	Facility Management
Objective	Maximum Return on Assets and Asset Utilization (rate)	Optimal work environment
Scope of work	Assets utilized by both primary business and support business functions of company/organization	Assets which support the primary business of a company/organization
Priority	Improve maintenance productivity and optimise equipment reliability	Improve user primary business productivity and effectiveness
Focus	Achieving Investor's profitability objectives while minimising assets' capital expenditures	End User/Occupier workplace needs and demands
Social responsibility	Out of AM's scope of work	Over 90% of corporate social responsibility initiatives are managed by FM

Figure 75 - Asset and Facility Management comparison.

Besides their clear differences about their objectives, both share many concepts and management method. One of their common scopes is in the areas of maintenance, operations, safety and logistics. Since the aim of the systems created during this thesis are intended for support activities, a facility management approach was considered for doing maintenance and asset tracking.

Both activities require the existence of an Asset Information Model. The AIM is formed by all models, data and documents required for the operation phase of an asset. The British standard PAS 1992:3 specifies the way AIM should be delivered in order to achieve BIM level 2 in relation to the operation and maintenance of the assets. The standard is flexible in allowing data and information to be stored within a discrete information model, or to be accessed via links to existing information systems.

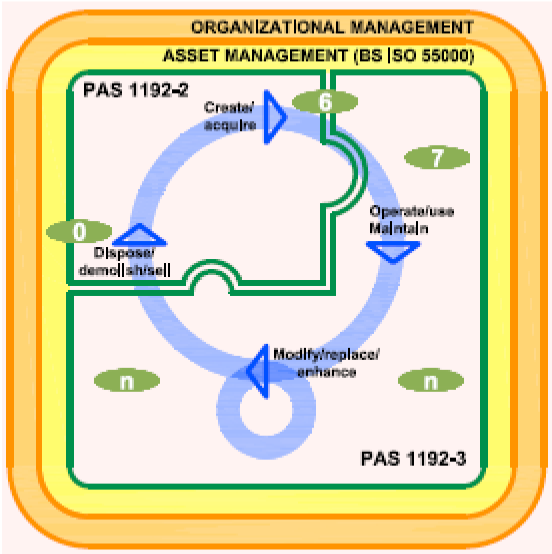


Figure 76 – PAS 1192-2, Asset Information Model elaboration process.

In the case of Trieste's Logistical Platform, the company was assigned not only for the design and construction but also for the management and maintenance of the structure for a thirty-years period. For this reason, it was thought that the creation of an AIM would be very helpful in order to follow the operation activities.

4.2.1. Maintenance Plan

The maintenance plan receipted consisted in a PDF with several pages divided into 5 parts:

1 – **Use Manual**: Lists of all assets including description and the correct way for using it, sorted by Element Code.

2 –**Maintenance Manual**: Lists of all assets where requirements, performance, possible anomalies found, controls and possible interventions required are explained.

3 – **Performances subprogram:** List of all requirements of assets performance, sorted by type.

4 – **Controls sub-program:** List of all necessary controls sorted by Control Code.

5 – **Interventions sub-program**: List of all interventions sorted by Intervention Code.

It must be mentioned that the Element Code mentioned in the Maintenance plan is composed by three levels of specification, the same as the Italian standard UNI 8290. However, it does not follow this standard, not even another international standard. The first level indicates the technologic unit.

01	PLATFORM DECK
02	INFRASTRUCTURE
03	PORT WORKS
04	CONFINED DISPOSAL
05	HYDRAULIC EQUIPMENT
06	BAIAMONTI DEVIATION
07	GROUNDWATER AND TERRAIN REMEDIATION
08	ELECTRIC AND SPECIAL EQUIPMENT

Figure 77 - Maintenance plan, Technologic Unit Classes.

The next level establishes the technological unit, for example for the hydraulic equipment:

05.01	HYDRAULIC AND FIREFIGHTING SYSTEM
05.02	SEWERAGE AND RAINWATER DRAINING
05.03	PUMPING EQUIPMENT

Figure 78 - Maintenance plan, Technologic Units inside Hydraulic Equipment Class.

Lastly, the third level represents the single element that must be maintained.

05.03.01	MANOMETERS
05.03.02	CENTRIFUGE PUMPS
05.03.03	LOW VOLTAGE PANEL
05.03.04	ACCUMULATION TANK
05.03.05	BUTTERFLY VALVES

Figure 79 - Maintenance plan, Elements inside Pumping Equipment Technologic Unit.

This codification has been adopted since not doing it would have mean to change the maintenance plan. So, for every element in the model has been assigned the “element code” parameter. It must be remarked that the list is not exhaustive, remaining many other objects without a classification code. The value “no data” was assigned to them, in order to show that they were not included in the maintenance plan.

The codes for performances, control and interventions uses a similar expression. The first three levels indicate the element to which the maintenance must be done, and a fourth one is included since for the same object may exists more than one control or intervention activity. This fourth level consists in a letter (“R” for performance requirement, “C” for control activity or “I” for intervention activity), plus two numbers.

Control Code	Control Title	Control Type	Frequency (weeks)
05.03.03.C01	Controllo centralina di rifasamento	Controllo a vista	8
05.03.03.C03	Verifica messa a terra	Controllo	8
05.03.03.C02	Verifica deli condensatori	Ispezione a vista	24
05.03.03.C04	Verifica protezioni	Ispezione a vista	24

Figure 80 - Maintenance plan, control lists for Accumulation Tank.

Since either interventions and controls must be done every certain amount of time (identified by frequency) it is possible to create a maintenance schedule thanks to it. Nevertheless, some intervention activities do not specify a frequency, for the contrary, they are supposed to be done "whenever it's necessary" or "when failure". For these cases a special consideration must be done.

4.2.2. Use of Trimble Connect

Since the company uses Trimble connect for collaboration and information management purposes, the idea of joining the maintenance plan with the model by attaching the correspondent PDF file to each element came up. This way, the responsible for following the maintenance schedule can search for the element in the mobile app and once there get the element and maintenance procedure information by clicking the object. Luckily the collaboration platform allows the uploading of PDF files.

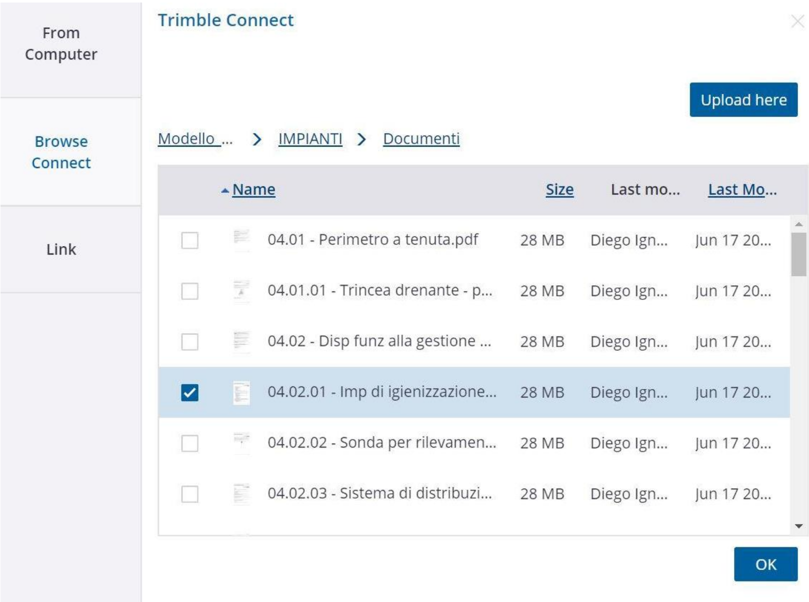


Figure 81 - PDF files loaded into Trimble Connect

The first idea of how to do the attaching was to select elements thanks to a filtering process by parameter. The parameter that would help to do the connection was the one called "Element Code", as it appeared in the maintenance plan. The problem of doing this was that filtering by parameter inside the platform was impossible.

So, searching for other alternatives, it came out the idea of opening the IFC tree and picking all the elements belonging to a certain family, as they are arranged in alphabetical order by its family name. However, neither the multiple selection inside the model tree was possible.

The last option considered was filtering according to its IFC class, and then selecting the items so the PDF files could be attached. However, as it was explained before, this was not possible since the viewer that allows filtering does not have the areal selection tool and vice versa. So, the idea of filtering and clicking one by one the elements was no sense.

The author decided to adopt the solution of attaching the necessaries PDF files to the general model, so each element will have a reduced maintenance plan just containing the information about elements present in the same file. The responsible of the maintenance just should click on the element, search for the element code through the lists of documents attached and open the respective PDF file.

To sum up, the file attachment failed. It might happen because of the limitation that a single user has. Administrators might have more management possibilities respect single users. If that is true, the author recommends doing the attachment, so information about the element's maintenance is clarified and accessible for everyone in the platform. If administrators are not able to do the attachment by multiple filtering, the author will consider this as a mistake that Trimble developers should solve in order to improve the platform potentiality.

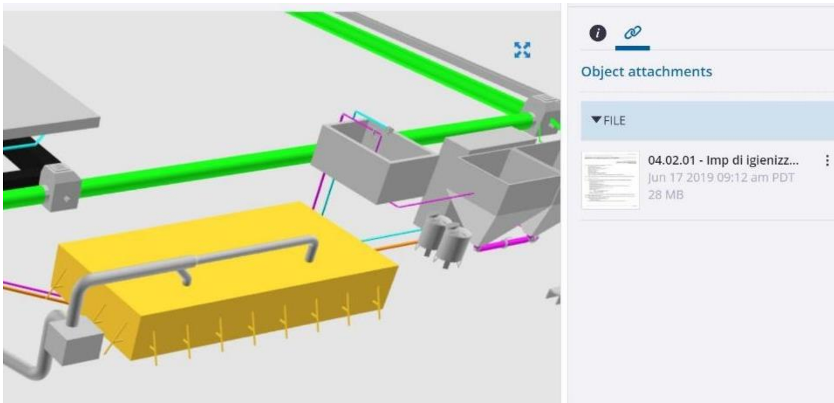


Figure 82 - Trimble Connect, document attached to an object.

The use of Trimble connect may be very helpful for identifying each element properties, like the code. However, as the filtering by properties option is not available, this means a one-way road. It is possible to navigate through the model and identify the objects, click them and get it properties, like its code. However, it is not possible to get the object position by having its code.

4.2.3. Openmaint

For the purpose of this thesis, the idea of trying a software specially created for facility management purposes came up. This kind of software is called Computerized Maintenance Management Systems. Since there are not student licenses for this kind of software, or they are given for a very reduced period, it was decided to look for an open source software. Searching in the web, an CMMS called OpenMAINT appeared, so it was decided to try it.

OpenMAINT is a ready-to-use application, which means that it is configured with all the essential basic storages, processes, reports and dashboards. It is very useful for medium and large organization to manage the mobile assets. By default, many folders in the form of tabs are included, some of them are buildings, installations and movable assets.

OpenMAINT is considered a servlet, which are server-side programs that handle clients' requests and return a customized or dynamic response for each request. To make it run, it was necessary to investigate about Java language, databases and so other concepts totally alien to a civil engineer. The way internet tutorials explain how to run the openMAINT includes the following requirements:

Java Development Kit: development environment for building applications, applets and components using the Java programming language.

PosgreSQL: Powerful open source object-relational database system.

PostGIS: Spatial database extender for PostgreSQL.

Apache Tomcat: Open source implementation of the Java Servlet, JavaServer Pages, Java Expression Language and Java Websocket technologies.

DMS Alfresco: Document management software that brings company content under control. Important files are easily found, shared and secured. Information flows to the right person, at the right time in the applications and devices people use to get their jobs done.

Once all the requirements are reached and correctly set up, the servlet should be running in the local server by running into the navigator localhost:8080/Openmaint. However, the author couldn’t make it run, probably because of incompatibility between the previous elements versions or a failing in setting up the database.

Nevertheless, another solution appeared thanks to the collaboration of a computer engineer that presented me the Docker alternative. Docker is the world’s largest library of container images. The advantage of its use is that containerized software will always run the same, regardless of the infrastructure. An application that runs openMAINT written in JAVA language was found in internet. The code was copied in a blank notepad file and then saved as a file with YML extension. The YAML Ain’t Markup Language (.yaml or .yml) has been inspired on the XML format. It is used not only for configuration files but also be used in many applications where data is being stored or transmitted, as this case requires.


docker-compose.yml - Blocco note

File Modifica Formato Visualizza ?

```
version: '2'
services:
  postgis:
    image: kpettijohn/postgis:9.4 #mdillon/postgis:9.5
    ports:
      - "5555:5432"
    environment:
      - POSTGRES_PASSWORD=test
      - POSTGRES_USER=postgres
  geoserver:
    image: kartoza/geoserver:2.6.1
    ports:
      - "8889:8080"
  bimserver:
    image: rsilva4/bimserver
    ports:
      - "8890:8080"
  openmaint:
    image: rsilva4/openmaint
    ports:
      - "8888:8080"
    environment:
      - BIM_ACTIVE=true
      - GIS_ENABLED=true
      - GEOSERVER_ON_OFF=on
      - DB_NAME=cmdbuild
    links:
      - postgis:postgres
      - geoserver
      - bimserver
```

Figure 83 - Openmaint YML code.

The way for making this file run in Windows 10 Pro/Enterprise operative system is by using the Powershell application. It requires to have already installed Docker for Desktop. The way to run a command in a new container is by using the command “docker run” being positioned into the folder where the YML file is placed.

After running the code, the following step is to enter to the local host in the port number 8888. This is where the web application should be running. The first step into the application is to enter with username “admin” and password “admin”.

Interface

OpenMAINT has a user-friendly interface, it does not take much time to understand it.

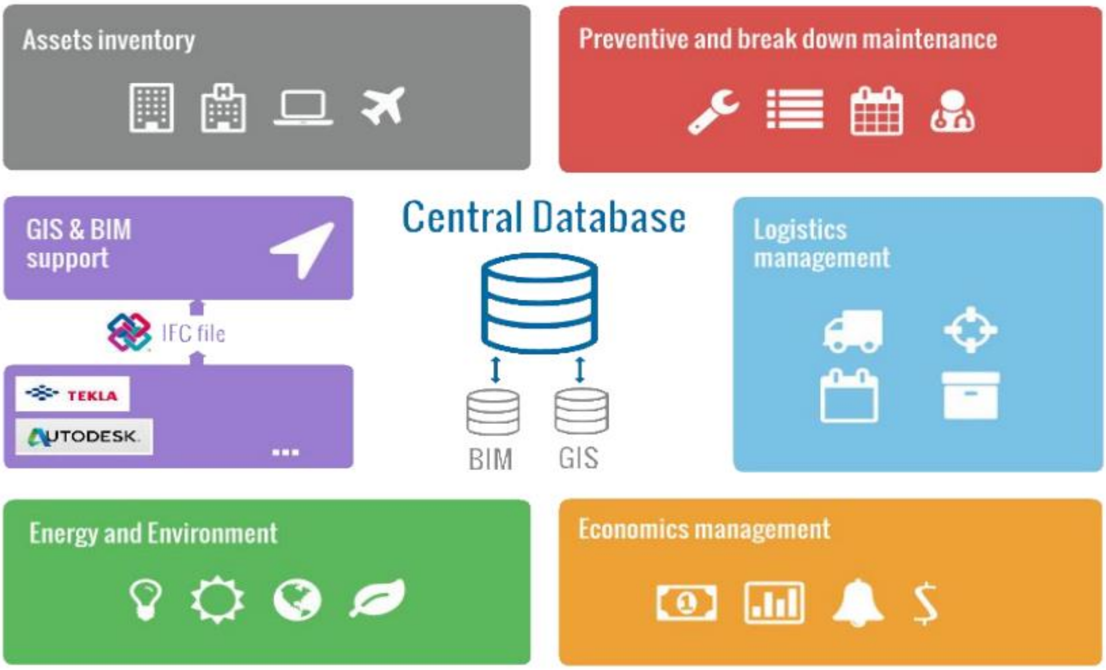


Figure 84 - Openmaint, main areas (OpenMaint, 2015).

Asset Inventory

Here you can manage the inventory of the facilities. It is the first section found when application starts. It is divided in different objects hierarchy.

GIS & BIM support

The servlet allows the user to load an IFC file, that will then appear in the buildings register. Once in the table of buildings, it is possible to give to the building a position in the world thanks to an interactive map. Another function allows to have a 3D view of the model, where it is possible to rotate and pick a certain object. The object is selected and from there it is possible to access to its position in the assets table.

Preventive and breakdown maintenance

The servlet has different workflow when it respects to a preventive or a breakdown maintenance activity. Both involves many different profiles and documents, being very complete. However, these functions may not be useful for the case study, not only because of the lack of information about the company structure, but also because it is not that big to need a warehouse where all assets are first stored and then transported.

Moreover, when trying to import the IFC file, an error occurs related to the BIM and GIS support, which depends on a PostreSQL extension. This way, the idea of using it was left aside, since the author's programming knowledge was not enough at the same time the effort would have not worth it.

4.2.4. Database Linking

The use of OpenMAIN failed but introduced the author into databases topic. The reality is that OpenMAINT is just a more complex database with some add ins like BIM, GIS and Documents manager. Databases are a large quantity of indexed digital information. Most popular databases are the relational ones, that consists on different tables related between them. The tables are conformed by rows (generally called records or tuples) and columns (also called attributes). The way tables are related one to each other is by sharing certain attributes.

Hopefully, Revit has the possibility of exporting projects to a database. In order to do this, it is necessary to download an add-in from the official Autodesk webpage, called Revit DB Link. This add-in allows to export to some of three types of drivers: Access 2000-2003, Access 2007 or Open Database Connectivity (ODBC).

For this thesis the Access 2007 driver was chosen, so database management system Microsoft Access was necessarily employed. With its rich and intuitive design tools, Access helps users create appealing and highly functional application in a minimal amount of time (Microsoft Office Oficial Webpage). It has the advantage of being included into the list of Microsoft Office products, so no download was required.

It should be remarked the database potentiality: They are very useful for input information in the model, no matter its nature. For this thesis it was used for maintenance scopes, but all kind of information about the model can be managed from there. In fact, all parameters that were introduced since now by manually clicking on objects or using schedules could have been completed by exporting the database, completing the desired fields, and importing the correspondent database.

Revit DB Link export process gives as a result an MBD extension file. The first picture the user gets when the database is opened, is terrifying: several tables representing each one a Revit entity or type of entity, and many others with information about layouts, lines or the project. It took some time to understand what they meant, but once the necessary tables were picked, they were isolated and grouped thanks to the use of grouping sets.

A critic the author makes to DB link is that exporting linked files is not allowed. However, this was imaginable since Revit linked files properties cannot be modified from the host model. This turned a disadvantage since the optimal solution would have been to have an asset information model that could be managed from a single file.

Consequently, the idea of having all databases linked into one came up. The first step was to create a blank database that will be used as host. Once created, to link tables from external database, the user must go to the External Data palette and click on the option New Data Source>From Database>Access. The "creating a linked table" option is selected. This way, every change made from the central database file, is also reflected on the single model database.

The connection between files is represented in the following schema:

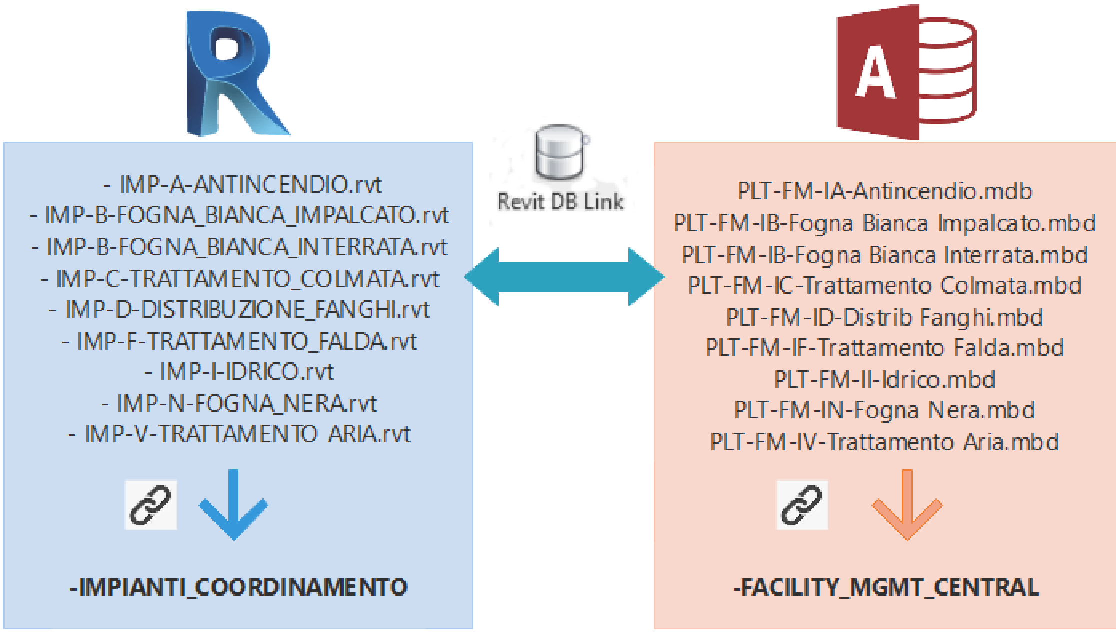


Figure 85 - Revit and Access files, linking graph.

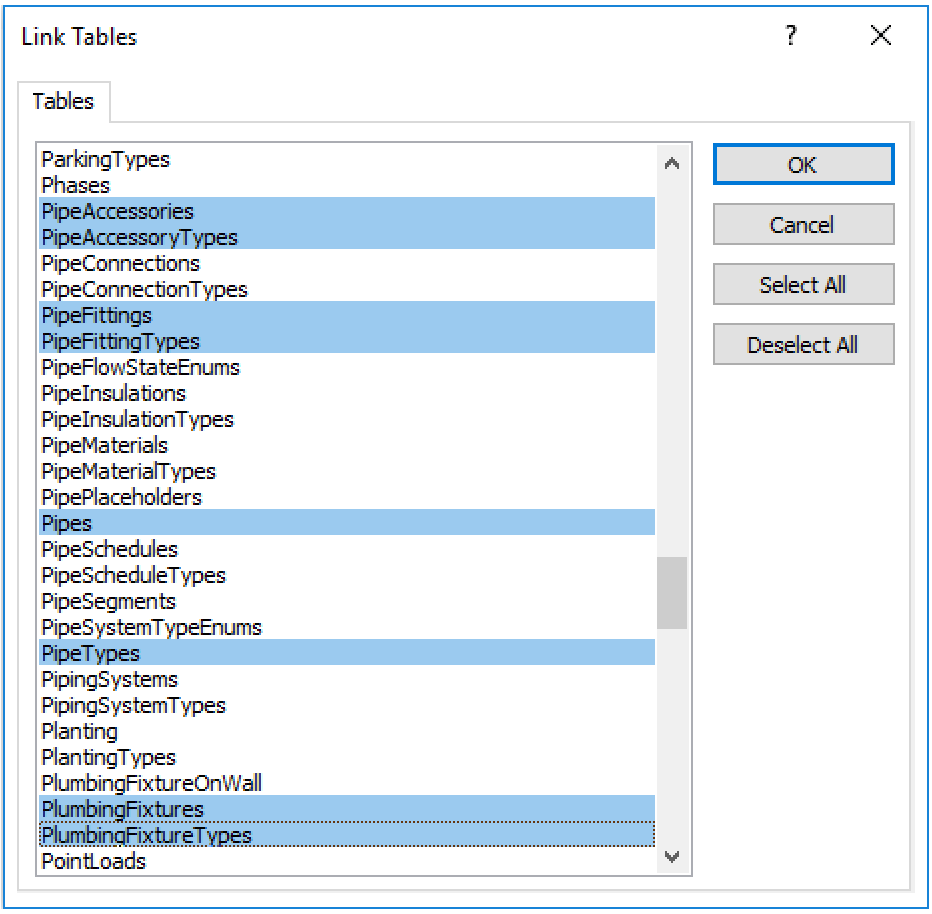


Figure 86 - Access, selecting desirable tables to link from another database.

Relations between linked tables, however, are not allowed. This is an inconvenient since it makes impossible to make inter-tables queries, what would be very helpful when special filters are required, as for example, a research of every mechanical equipment that is positioned inside the perimetral cord. Nevertheless, custom grouping and using a name convention for tables help the author order tables by his criteria. Renaming a linked table does not reflects into the file database, luckily, because that would have cause problems in the database importing process into Revit. By making use of these benefits, a well-organized list of assets and assets types has been created.

From this central database file, it is possible to change some of the parameters values. The responsible for the maintenance, for example, would be able to fill the required parameters when needed. Each time the models are required to be updated, it is matter of using Revit DB link extension to import the database referred to the file.

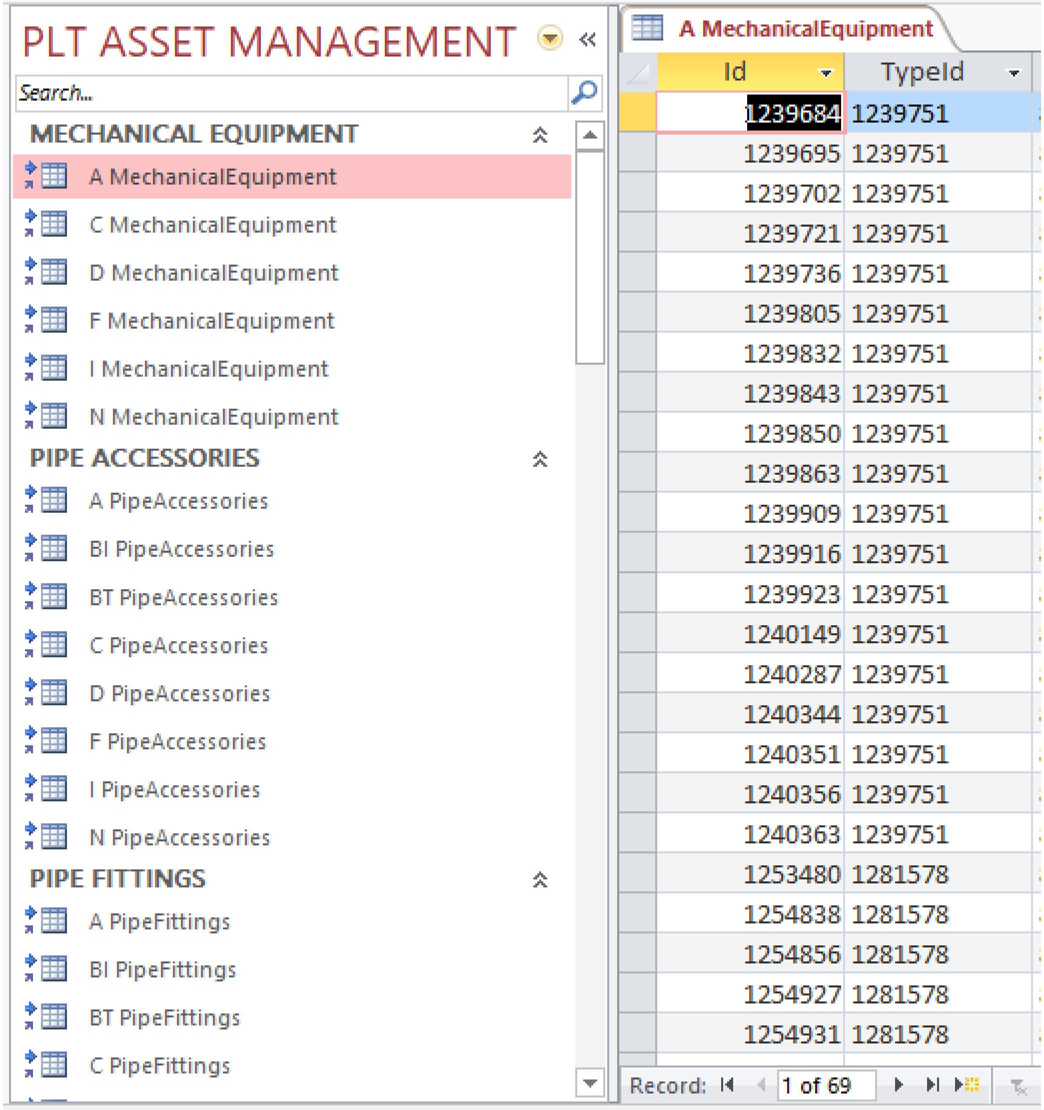


Figure 87 - Access, grouping order on the central database.

Types of Maintenance

Something interesting that can be taken from OpenMAINT is the division between preventive and breakdown maintenance. As they belong to different nature, they need to be treated separately.

The breakdown maintenance includes all activities related to repair or replacement of a certain equipment because it cannot continue performing its function. This may occur because a planned or an unplanned event. Planned events are usually considered in run-to-failure maintenance models, while unplanned events usually drive to corrective maintenance.

Both types of maintenance, breakdown and corrective were taken into account in the model by the inclusion of an integer-type parameter that indicates the replacement frequency, in years. It was called "ReplaceFreqYears". Some elements in the maintenance plan are considered within the interventions, some others, on the contrary, are not considered since its life cycle is long enough to not be considered through the thirty-years maintenance period. The last ones have been considered with a replacement frequency of 99 years, the same as the elements where its replacement is considered "whenever is necessary". Consequently, these elements will not be shown during the thirty-years period as necessary to replaced.

Preventive maintenance, on the contrary, consists of all activities intended to prevent the likelihood of an unexpected breakdown. These activities are less expensive than the breakdown maintenance, despite being required more often.

Both controls and interventions schedules contain preventive maintenance activities. They were introduced in the model within the parameter called "CtrlFreqDays", and its value represents the smaller frequency among all preventive maintenance activities, in days.

The last parameter included was the personal responsible for doing the maintenance, in order to make a difference between the different users that participate in the maintenance plan. It was created an extra parameter called "Management Responsible", that in the actual database can be used as a filter parameter, and maybe in a possible expansion can be used for managing different users with different permissions inside the database.

Input parameters

The facility manager or whoever is responsible for tracking the maintenance activities, interact with the model within input parameters. The input parameters added for this aim were called "Last Replacement Day" and "Last Control Day". As the date type of field is not supported by Revit, it was necessary to create a system that identifies each day with a number. For this new system, the construction start is considered the number 1 day. The starting value for these parameters is taken from the schedule created in synchro: Install Day is the first value for Replacement Day.

A MechanicalEquipment | BI PlumbingFixtures | A Pipes | A PipeAccessories

SystemNam	Size	Comment	Mark	WBS	Code	Install Date	Install Day	Last Replace	Last Replace
Antincendio	90 mmø-90 mmø		147	T.12	PLT.IA.SS.42.41.VLVSRC	17/5/2018	830	17/5/2018	830
Antincendio	160 mmø-160 mmø		154	CO.51-55	PLT.IA.CO.55.12.VLVSRC	7/11/2018	1004	7/11/2018	1004
Antincendio	90 mmø-90 mmø		158	CO.51-55	PLT.IA.CO.52.31.VLVSRC	7/11/2018	1004	7/11/2018	1004
Antincendio	160 mmø-160 mmø		171	IM.02	PLT.IA.IM.02.21.VLVSRC	20/8/2017	560	20/8/2017	560
Antincendio	160 mmø-160 mmø		172	IM.11	PLT.IA.IM.11.11.VLVSRC	5/9/2017	576	5/9/2017	576

Figure 88 - Access, parameters completing.

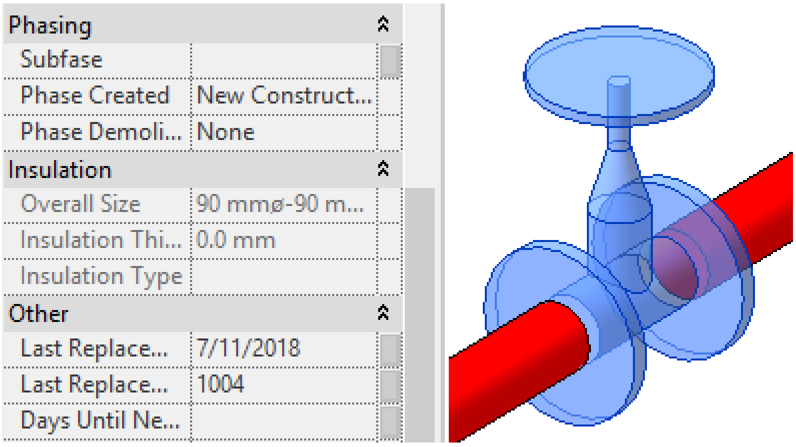


Figure 89 - Revit, result of the database import process

Once parameters are filled, the day for the next control or replacement can be calculated using calculated values inside schedules inside Revit. For this purpose, a new schedule was created, where all parameters related to the maintenance were introduced. The "Next replacement" calculated value consisted on obtaining the day where is supposed that assets' lifecycle finishes. However, since the replacement frequency of elements that were scheduled to be replaced "whenever is necessary" adopted a high value (99 years), a conditional formula was introduce so to return only elements that need to be replaced within the thirty first years of operational activities.

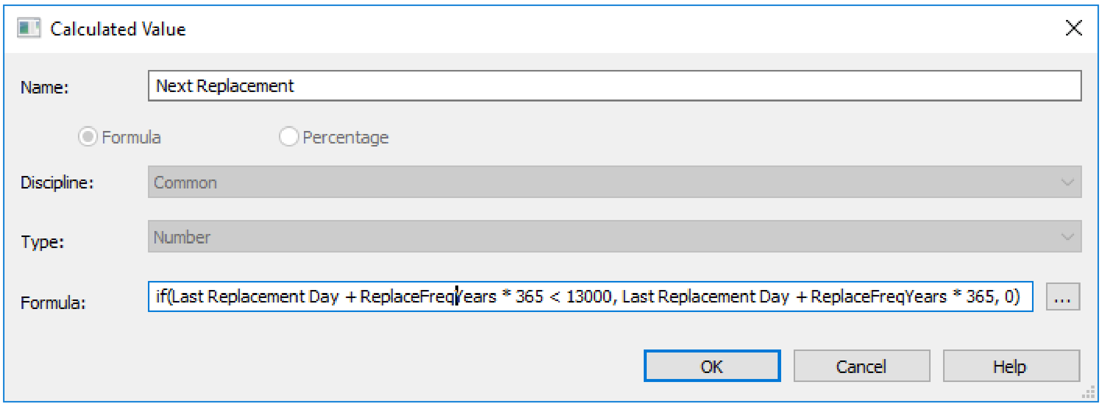


Figure 90 - Revit Next Replacement calculated value

The schedule resulted as it is shown in the following picture:

<Replacements Schedule>

A	B	C	D	E
Code	Last Replaceme	Last Replacement	ReplaceFreqYear	Next Replace
PLT.IA.TN.01.52.GOMITO	746	22/02/2018	99	0
PLT.IA.TN.01.53.GOMITO	746	22/02/2018	99	0
PLT.IA.TN.02.51.GOMITO	760	08/03/2018	99	0
PLT.IA.TN.03.51.GOMITO	767	15/03/2018	99	0
PLT.IA.TN.05.51.GOMITO	781	29/03/2018	99	0

Figure 91 - Revit Schedule, replacements.

At this point it is important to show that the way to proceed has more disadvantages than advantages. The following flow chart helps identify the steps carried out.

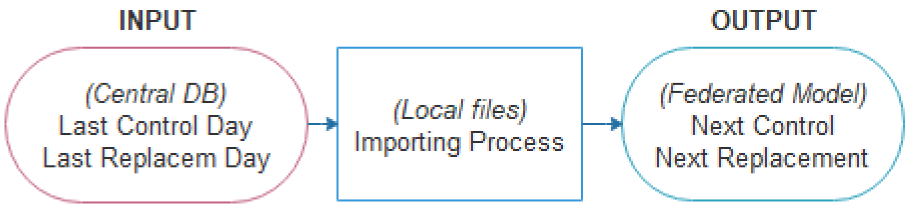


Figure 92 - Flowchart Access-Revit linking

First, the fact that Revit does not work with date parameters, makes everything more difficult. It is unthinkable to have to look at a table each time a translation between dates and the numerical system adopted is done. Let's suppose that in a Revit future version, date parameters are available, so to continue with the analysis.

To get Revit schedules values updated, first, it is required to update the model by using Revit DB Link to import the linked databases inside each discipline model. Then, close them and open the federated model. The problem is not only time consuming, but the requirement of a computer just to have the model updated. Of course, the activity of updating the model should be casually done, since no important modifications took place.

This last paragraph drives the author to an important conclusion: control and replacement tracking must be done inside access, where the user, by using a form, register all controls done day by day. These forms would be registered into a table, consisting in four fields: when and what control was made, who made it, and to which element. Date can be automatically filled thanks to the use of (today) values. The person who made the control can be also automatically filled by reading the user that filled the form. This way, the operator would just need to select the element and the control done, that can be selected from a menu when the element is identified.

This automatization not only makes operation works simpler, but it is also helpful for identifying when a mistake was made and who was the responsible. However, Access is still a very basic tool respect from others in market. It does not give the possibility of viewing the element at which refers the registers, since it is just a database software. So, if this option is used, a new code applicated only of the maintenance objects should be done. This code must be easily understandable for the user, since it is not the possibility of looking them at the model. In the case of pipes and fittings, this code must englobe a group of them, since it is unthinkable to register them as single elements when a clean maintenance is done. The use of Trimble connect may help to identify which element is being maintained to check the form, but it makes impossible to identify in the platform where are the elements that must be maintained that day are placed.

These problems are avoided with the use of CMMS where BIM models can be introduced, such as OpenMAINT. The company responsible for the operational activities should take them into account for a more efficient work, but they must know that managing this kind of software require an inversion on training personal.

5. Conclusion

To conclude with this thesis, the author would like to sum up what he has learned during his first experience with BIM methodology.

The modelling process is very tedious at first, for unexperienced users. Plenty of mistakes are made due to the lack of knowledge about the software and their tools. However, it is important to be alert to these mistakes in order not to repeat them, since working in a wrong way leads to inconsistency problems that make the model useless for being used for other scopes.

The use of classification codes is a very interesting option but the fact of filling their values is a tiring and time-consuming activity. It is worthless to use more than one system classification, so before starting a project, it must be clear what classification will be used. Actually, the most complete and consistent seems to be Uniclass. However, they are being continuously updated, so in the future it may result outdated respect from others. When working in different countries it may happen that a certain standard is most commonly used. In this case, it may result convenient to follow it in order to improve collaboration with other companies and between the different task teams.

The creation of a BIM guide with specification on standards is strongly useful for the modeller to have an idea which are the limits of the model. Specifying the parameters that will be used help the designers to avoid information inconsistencies and consequently hard work changing parameters values. LOD specification not only improve communication between contractors but also helps the designer identify when something is worth to be modelled and when becomes a time waste.

Models are a representation of reality, and not the reality itself. Beginner modellers use to overdetail models to make it seem as real as possible. The author has made the same mistake in many cases, since the models receipted were also overdetailed. In cases where there are no LOD specifications, like in this thesis case, the author must be capable of setting the limits regarding to the available time and resources. After some time, modelling, it was decided that every element in maintenance plan should be created as a family. The scope of the model must orient the modeller which elements are necessary and which level of detail introduce. Creating pipe supports was a mistake, but they can be used for estimating the cost of the complete piping system. But if every pipe support in the perimetral cord walls had been placed, it would have meant weeks of useful work, since they had nothing to do with the 4D simulation nor the maintenance plan.

It must be remarked that working with BIM based software usually requires a high computational potential, so, companies that would want to introduce BIM methodology must think in making an investment not only in training personal but also in technology. At the beginning of this thesis, the work was done in a commercial notebook that allowed the author to work in one model at a time. But then, when it was necessary to work in different models at the same time, it was impossible to show everything in a sixteen-inches screen.

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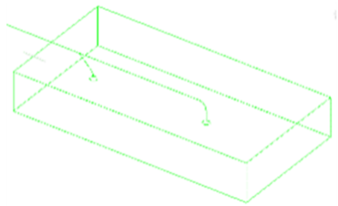
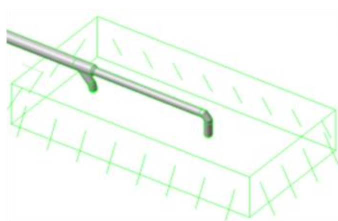
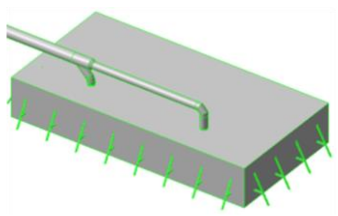
ANNEX A – LOD TABLES

LOD TABLE - BIOFILTER

General Info	Family	**Biofiltro**	[x] Loadable	Biofilter consisting on modular isolating panels retained by galvanized steel columns. Dimensions: 12x6x2 m, 72 m2.
	Category	**Air Terminal**	[ ] System	
	Sub-category	**-**	[ ] In-place	
	Type	**Standard**		
	File Name	**IMP-V- Biofiltro.rfa**		

	Detail Level	Explanation	Representation	Critics and Comments
LOG	Coarse	Few lines made around the solids represented. Supports were not included.		The family has been created from scratch, since it was not found into Revit predefined Libraries. The sketching was possible thanks to a provided floor plan CAD, while the height has been copied from a drawing present in the general report PDF.
	Medium	Inclusion of the supports just to include a little more detail to the family.		
	Fine	Consisted in all extrusions, a square to represent the main body, and a non-conventional shape to represent the supports just to look like the ones represented in the PDF.		

Connectors	**Connector 1**	Mechanical	
		Flow Configuration	**Calculated**
		Flow Direction	**Out**
		System Classification	**Fire Protection Wet**
		Geometric	
		Diameter	**90 mm**

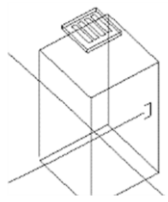
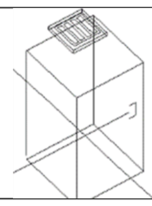
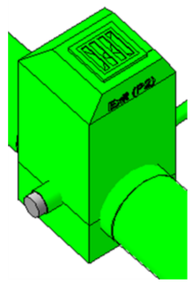
LOI	**Family Parameters**	System Parameters	
		System Type	***Ehaust Air***
		System Name	**Aspiratore-Trattamento**
		IFC Parameters	
		IFCExportAs	**IfcFlowTreatmentDevice**
		IFCExportType	**-**
		Family Parameters	
		Host	**No**
		Shared	**No**
		Cut with voids when loaded	**Yes**
		Omniclass Number	**23.75.70.21.31**
		Omniclass Title	**Climate Control (HVAC)**
		Manufacturer	**-**
		Cost	**-**

Project Shared Parameters	**Types**	Classification	
		Omniclass 2015	**23-27 57 35 13**
		Masterformat 2014	**D3060.30**
		Uniformat 2010	**Pr_65_57_95_07**
		UNI-8290 1981	**05.04.03**
		Maintenance Plan	
		Elemento Manutenibile	**04.02.03**
		ReplaceFreqYears	**6**
		CtrlFreqDays	**2016**
		Management Responsible	**Tecnici di livello superiore**
	Instances	Scheduling	
		WBS	**TT**
		Code	**PLT.IV.TT.42.00.BIOFLT**
		Install Day	**845**
		Install Date	**1/6/2018**

LOD = C

LOD TABLE - DRY WELL

General Info				
Family	**Pozzetto di scarico**			Consists on many pre-cast concrete pieces. In the top is connected to a rainwater drain, where is placed a basket that retain granular material.
Category	**Pipe Fitting**	x	Loadable	
Sub-category	-		System	
Type	**1000 1000 315 200**		In-place	
File Name	**IMP-B-Pozzetto_di_scarico.rfa**			

LOG	Detail Level	Explanation	Representation	Critics and Comments
	Coarse	Few lines that represent the edges in case of extrusion, or the axis in case of sweep volumes.		Since in and out diameters are very important because on them depend all the other dimensions and costs, it was decided to create different types depending on these diameters. Other geometric instance parameters take part: Height and in/out angles. This has the advantage of having to select one by one its height in order to respect the 0,2% slope for pipes.
	Medium	Just an introduction of more model lines to the Coarse level of detail drawing.		
	Fine	3D geometry made thanks to the creation of elements by any way: Extrusion, Sweep, Revolution, Blend. An aditional "Exit" signal was introduced in order to quickly indentificate the "out" pipe.		

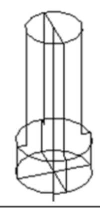
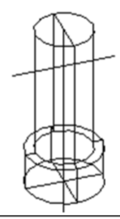
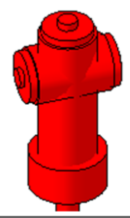
Connectors					
Connector 1	Flow Configuration	**Calculated**	Connector 3	Flow Configuration	**Calculated**
	Flow Direction	**In**		Flow Direction	**In**
	System Classification	**Fitting**		System Classification	**Fitting**
	Diameter	**1000 mm**		Diameter	**315 mm**
Connector 2	Flow Configuration	**Calculated**	Connector 4	Flow Configuration	**Calculated**
	Flow Direction	**Out**		Flow Direction	**In**
	System Classification	**Fitting**		System Classification	**Fitting**
	Diameter	**1000 mm**		Diameter	**200 mm**

LOI						
Family Parameters	System Parameters		Project Shared Parameters	Types	Classification	
	System Type	***Sanitary - Rainwater***			Omniclass 2015	**23-39 29 11 13**
	System Name	***Sanitary - Rainwater 28***			Masterformat 2014	**D2030.30**
	IFC Parameters				Uniformat 2010	**Pr_65_52_01_20**
	IFCExportAs	**IfcWasteTerminal**			UNI-8290 1981	***05.03.03***
	IFCExportType	-			Maintenance Plan	
	Family Parameters				Elemento Manutenibile	**05.02.02**
	Host	**Face**			ReplaceFreqYears	**Non corrisponde**
	Shared	**No**			CtrlFreqDays	**336**
	Cut with voids when loaded	**Yes**			Management Responsible	**Specialisti vari**
	Omniclass Number	**23.60.30.11.14**		Instances	Scheduling	
	Omniclass Title	**Pipework Fittings**			*WBS*	**T.09**
	Manufacturer	-			Code	***PLT.IB.TN.09.01.PZZTSC***
	Cost	**0**			Install Day	**809**
					Install Date	**26/4/2018**

LOD = C

LOD TABLE - ABOVE GROUND FIRE HYDRANT

General Info	Family	**Idrante a colonna soprasuolo**	x Loadable	Dispositive connected to a hydric supply. They can be classified depending on how the connection is done: axial or alongside.
	Category	**Mechanical Equipment**	System	
	Sub-category	**-**	In-place	
	Type	**80 mm**		
	File Name	**IMP-A-Idrante_a_colonna_soprasuolo-Oppo.rfa**		

	Detail Level	Explanation	Representation	Critics and Comments
LOG	Coarse	Few lines that had been made by the author since they actually weren't in the original file.		The family was hardly found in the "site" folder, inside the US Metric library, thanks to a search in the windows explorer. The geometry was perfect, just some changes were made: a connector has been created, and the category was changed to "Mechanical equipment".
	Medium	Just an introduction of more model lines to the Coarse level of detail drawing.		
	Fine	3D geometry as it was saved in the Revit US Metric library. A join of two cylinders revolved, one around a vertical axis and the other around a horizontal perpendicular axis.		

Connectors	**Connector 1**	Mechanical	
		Flow Configuration	**Calculated**
		Flow Direction	**Out**
		System Classification	**Fire Protection Wet**
		Geometric	
		Diameter	**80 mm**

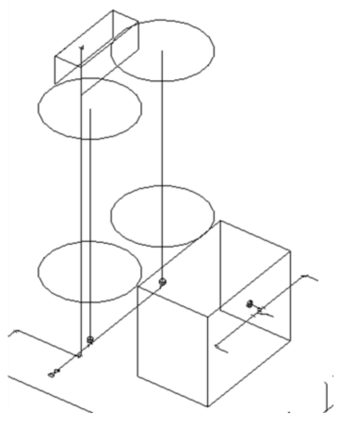
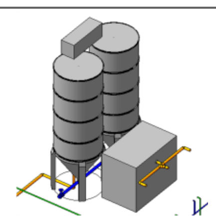
LOI	**Family Parameters**	System Parameters	
		System Type	***Fire Protection Wet***
		System Name	***Antincendio***
		IFC Parameters	
		IFCExportAs	**IfcFlowTerminal**
		IFCExportType	-
		Family Parameters	
		Host	**No**
		Shared	**No**
		Cut with voids when loaded	**Yes**
		Omniclass Number	**23.65.70.17.11.11**
		Omniclass Title	**Fire Hydrants**
		Manufacturer	-
		Cost	-

Project Shared Parameters	**Types**	Classification	
		Omniclass 2015	**23-29 25 13 11**
		Masterformat 2014	**D4010.10**
		Uniformat 2010	**Pr_70_55_97_01**
		UNI-8290 1981	***06.01.03***
		Maintenance Plan	
		Elemento Manutenibile	**05.01.02**
		ReplaceFreqYears	**No data**
		CtrlFreqDays	**168**
		Management Responsible	**Idraulico**
	Instances	Scheduling	
		WBS	**T.12**
		Code	***PLT.IA.TN.12.90.IDRSPR***
		Install Day	**830**
		Install Date	**17/5/2018**

LOD = D

LOD TABLE – CONFINED DISPOSAL WATER TREATMENT EQUIPMENT

General Info	Family Category Sub-category Type File Name	**Impianto TAC** **Mechanical Equipment** - **Standard** **IMP-C-Impianto_TAC.rfa**	x Loadable System In-place	Based on a clariflocculation treatment with the possibility of being derived to a chemical-physical station, correspondent to the groundwater treatment system. It is also integrated with sand filters.

	Detail Level	Explanation	Representation	Critics and Comments
LOG	Coarse	Few lines that represent the edges in case of extrusion, or the axis in case of sweep volumes.		The connection to the chemical and physical station was left aside since they correspond to diverse systems. Furthermore, the derivation to this equipment is thought to be done only after the 80% of the sediments have already decanted. During the first stage of decantation the clariflocculation process within the filtering is enough to treat water.
	Medium			
	Fine	3D geometry made by extrusion in the case of prisms and revolution for the separators, which are the three meters of diameter towers.		

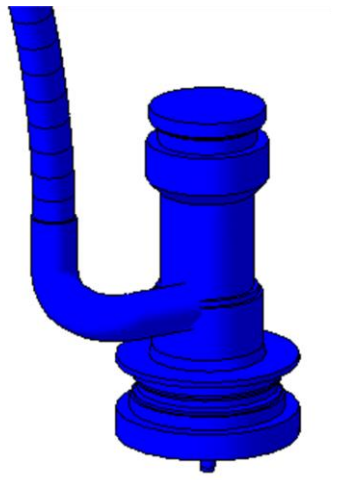
Connector	**Connector 1**	Flow Configuration Flow Direction System Classification Diameter	**Calculated** **In** **Other** **160 mm**	**Connector 3**	Flow Configuration Flow Direction System Classification Diameter	**Calculated** **Out** **Other** **150 mm**
	Connector 2	Flow Configuration Flow Direction System Classification Diameter	**Calculated** **Out** **Sanitary** **160 mm**	**Connector 4**	Flow Configuration Flow Direction System Classification Diameter	**Calculated** **Out** **Other** **150 mm**

LOI	**Family Parameters**	System Parameters		**Project Shared Parameters**	**Types**	Classification	
		System Type	***Disposal Water Treatment***			Omniclass 2015	**23.70.50.21**
		System Name	***Pompaggio-TAC***			Masterformat 2014	**G1050.10**
		IFC Parameters				Uniformat 2010	**Pr_60_55_96**
		IFCExportAs	**IfcFlowTreatmentDevice**			UNI-8290 1981	***No data***
		IFCExportType	-			Maintenance Plan	
		Family Parameters				Elemento Manutenibile	**04.02.04**
		Host	**No**			ReplaceFreqYears	**No data**
		Shared	**No**			CtrlFreqDays	**28**
		Cut with voids when loaded	**Yes**			Management Responsible	**Specialisti vari**
		Omniclass Number			**Instances**	Scheduling	
		Omniclass Title	**Liquid Waste Collection and Removal**			*WBS*	**TT**
		Manufacturer	-			Code	***PLT.IC.TT.11.00.IMPTAC***
		Cost	-			Install Day	**845**
						Install Date	**1/6/2018**

LOD = C

LOD TABLE - DRAGFLOW PUMP

General Info	Family	**Pompa Dragflow**	x Loadable	Pump specially created for mineral industry. It can draw centimetre-sized elements. Two pumps in series are used in order to guarantee a faster sediments discharge, a continuous operation, and the possibility of safely maintain them.
	Category	**Mechanical Equipment**	System	
	Sub-category	**-**	In-place	
	Type	**Standard**		
	File Name	**IMP-D-Pompa_Dragflow-Dragflow.rfa**		

LOG	**Detail Level**	**Explanation**	**Representation**	**Critics and Comments**
	Coarse	The shape in the catalogue was copied and revolved. An extra arm was made thanks to sweeping a 3D line.		Since it was one of the few elements where manufacturer and model were decided, it was also looked at his price and inserted in case a future 5D analysis was done.
	Medium			
	Fine			

Connector	**Connector 1**	Flow Configuration	**Calculated**	**Connector 2**	Flow Configuration	**Calculated**
		Flow Direction	**In**		Flow Direction	**Out**
		System Classification	**Other**		System Classification	**Other**
		Diameter	**250 mm**		Diameter	**80 mm**

LOI	**Family Parameters**	System Parameters		**Project Shared Parameters**	**Types**	Classification	
		System Type	***Beach Nourishment***			Omniclass 2015	**23-39 45 19**
		System Name	***Distribuzione Fanghi***			Masterformat 2014	**G1050.60**
		IFC Parameters				Uniformat 2010	**Pr_65_53_96_85**
		IFCExportAs	**IfcFlowMovingDevice**			UNI-8290 1981	***No data***
		IFCExportType	**-**			Maintenance Plan	
		Family Parameters				Elemento Manutenibile	**04.02.05**
		Host	**No**			ReplaceFreqYears	**10**
		Shared	**No**			CtrlFreqDays	**1**
		Cut with voids when loaded	**Yes**			Management Responsible	**Tecnici di livello superiore**
		Omniclass Number	**23.60.30.21**		**Instances**	Scheduling	
		Omniclass Title	**Pumps**			*WBS*	**IM.54**
		Manufacturer	**Dragflow**			Code	***PLT.ID.IM.54.40.DRGFLW***
		Cost	**17000**			Install Day	**1037**
						Install Date	**10/12/2018**

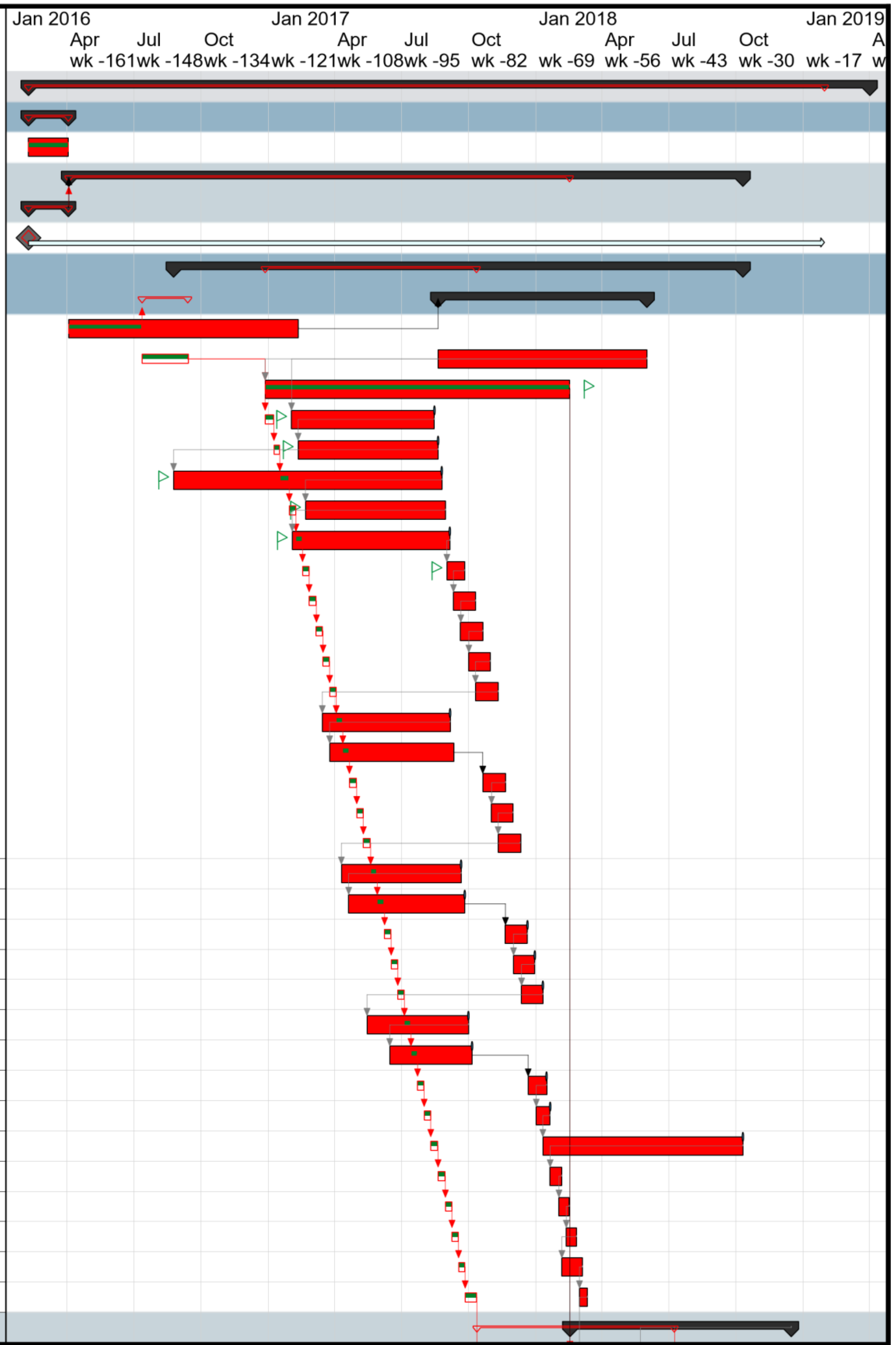
LOD = D

Nested Families: -

Files where is found: **IMP-D-DISTRIBUZIONE FANGHI.rvt**

ANNEX B - SCHEDULES

	ID	Name	Duration	BL Early Finish	BL Early Start	Actual Start	Actual Finish	Resources Code (Text1)
1	0.0.00	Project - PLT	1044d	07:59 1/1/3001	07:59 1/1/3001	08:00 8/2/2016	17:00 1/4/2019	
4	1.1.00	1.a - Approntamento cantiere - Uffici	55d	17:00 2/4/2016	08:00 8/2/2016	08:00 8/2/2016	17:00 2/4/2016	
5	1.1.01	Uffici	55d	17:00 2/4/2016	08:00 8/2/2016	08:00 8/2/2016	17:00 2/4/2016	UF
6	2.0.00	2 -	815d, 1m	17:00 15/2/2018	08:00 3/4/2016	08:00 3/4/2016	08:01 10/10/2018	
3	1.0.00	1 -	55d	17:00 2/4/2016	08:00 8/2/2016	08:00 8/2/2016	17:00 2/4/2016	
2	0.0.01	Inizio	0d		08:00 8/2/2016	08:00 8/2/2016		
11	2.4.00	2.d - Pali di fondazione ed elevazione impalcato	672d, 1m	17:00 11/10/2017	08:00 27/12/2016	08:00 24/8/2016	08:01 10/10/2018	
8	2.2.00	2.b - Realizzazione impianti TAF e TAC	285d	17:00 12/9/2016	08:00 12/7/2016	08:00 20/8/2017	08:00 1/6/2018	
7	2.1.00	2.a- Verifiche analitiche cumulo rovescio	209d	17:00 11/7/2016	08:00 3/4/2016	08:00 3/4/2016	17:00 10/2/2017	
9	2.2.01	Impianto TAF/TAC	285d	17:00 12/9/2016	08:00 12/7/2016	08:00 20/8/2017	08:00 1/6/2018	TT
10	2.3.00	2.c - Scavo per rimozione cumuli bonifica a terra e rifiuti, progr collaudo fondo scavo	416d	17:00 15/2/2018	08:00 27/12/2016	08:00 27/12/2016	17:00 15/2/2018	
12	2.4.01	Impalcato 01	195d	17:00 7/1/2017	08:00 27/12/2016	08:00 1/2/2017	08:00 15/8/2017	IM.01
13	2.4.02	Impalcato 02	191d, 1m	17:00 15/1/2017	08:00 8/1/2017	08:00 10/2/2017	08:01 20/8/2017	IM.02
14	2.4.03	Impalcato 03	261d, 1m	17:00 28/1/2017	08:00 16/1/2017	08:00 24/8/2016	08:01 25/8/2017	IM.03
15	2.4.04	Impalcato 04	191d, 1m	17:00 6/2/2017	08:00 29/1/2017	08:00 20/2/2017	08:01 30/8/2017	IM.04
16	2.4.05	Impalcato 05	215d, 1m	17:00 15/2/2017	08:00 7/2/2017	08:00 2/2/2017	08:01 5/9/2017	IM.05
17	2.4.06	Impalcato 06	24d, 1m	17:00 24/2/2017	08:00 16/2/2017	08:00 1/9/2017	08:01 25/9/2017	IM.06
18	2.4.07	Impalcato 07	30d, 1m	17:00 6/3/2017	08:00 25/2/2017	08:00 10/9/2017	08:01 10/10/2017	IM.07
19	2.4.08	Impalcato 08	30d, 1m	17:00 15/3/2017	08:00 7/3/2017	08:00 20/9/2017	08:01 20/10/2017	IM.08
20	2.4.09	Impalcato 09	29d, 1m	17:00 24/3/2017	08:00 16/3/2017	08:00 1/10/2017	08:01 30/10/2017	IM.09
21	2.4.10	Impalcato 10	31d, 1m	17:00 2/4/2017	08:00 25/3/2017	08:00 10/10/2017	08:01 10/11/2017	IM.10
22	2.4.11	Impalcato 11	175d	17:00 11/4/2017	08:00 3/4/2017	08:00 15/3/2017	17:00 5/9/2017	IM.11
23	2.4.12	Impalcato 12	170d	17:00 20/4/2017	08:00 12/4/2017	08:00 25/3/2017	17:00 10/9/2017	IM.12
24	2.4.13	Impalcato 13	31d, 1m	17:00 30/4/2017	08:00 21/4/2017	08:00 20/10/2017	08:01 20/11/2017	IM.13
25	2.4.14	Impalcato 14	29d, 1m	17:00 9/5/2017	08:00 1/5/2017	08:00 1/11/2017	08:01 30/11/2017	IM.14
26	2.4.15	Impalcato 15	30d, 1m	17:00 19/5/2017	08:00 10/5/2017	08:00 10/11/2017	08:01 10/12/2017	IM.15
27	2.4.16	Impalcato 16	164d	17:00 28/5/2017	08:00 20/5/2017	08:00 10/4/2017	17:00 20/9/2017	IM.16
28	2.4.17	Impalcato 17	159d	17:00 7/6/2017	08:00 29/5/2017	08:00 20/4/2017	17:00 25/9/2017	IM.17
29	2.4.18	Impalcato 18	30d, 1m	17:00 16/6/2017	08:00 8/6/2017	08:00 20/11/2017	08:01 20/12/2017	IM.18
30	2.4.19	Impalcato 19	29d, 1m	17:00 25/6/2017	08:00 17/6/2017	08:00 1/12/2017	08:01 30/12/2017	IM.19
31	2.4.20	Impalcato 20	29d, 1m	17:00 4/7/2017	08:00 26/6/2017	08:00 12/12/2017	08:01 10/1/2018	IM.20
32	2.4.21	Impalcato 21	139d	17:00 13/7/2017	08:00 5/7/2017	08:00 15/5/2017	17:00 30/9/2017	IM.21
33	2.4.22	Impalcato 22	113d	17:00 22/7/2017	08:00 14/7/2017	08:00 15/6/2017	17:00 5/10/2017	IM.22
34	2.4.23	Impalcato 23	25d, 1m	17:00 31/7/2017	08:00 23/7/2017	08:00 21/12/2017	08:01 15/1/2018	IM.23
35	2.4.24	Impalcato 24	19d, 1m	17:00 9/8/2017	08:00 1/8/2017	08:00 1/1/2018	08:01 20/1/2018	IM.24
36	2.4.25	Impalcato 25	273d, 1m	17:00 19/8/2017	08:00 10/8/2017	08:00 10/1/2018	08:01 10/10/2018	IM.25
37	2.4.26	Impalcato 26	16d, 1m	17:00 29/8/2017	08:00 20/8/2017	08:00 20/1/2018	08:01 5/2/2018	IM.26
38	2.4.27	Impalcato 27	14d	17:00 7/9/2017	08:00 30/8/2017	08:00 1/2/2018	08:00 15/2/2018	IM.27
39	2.4.28	Impalcato 28	14d, 1m	17:00 16/9/2017	08:00 8/9/2017	08:00 11/2/2018	08:01 25/2/2018	IM.28
40	2.4.29	Impalcato 29	28d, 1m	17:00 25/9/2017	08:00 17/9/2017	08:00 5/2/2018	08:01 5/3/2018	IM.29
41	2.4.30	Impalcato 30	11d, 1m	17:00 11/10/2017	08:00 26/9/2017	08:00 1/3/2018	08:01 12/3/2018	IM.30
42	3.0.00	3 -	302d, 1m	17:00 8/7/2018	08:00 12/10/2017	08:00 16/2/2018	08:01 15/12/2018	



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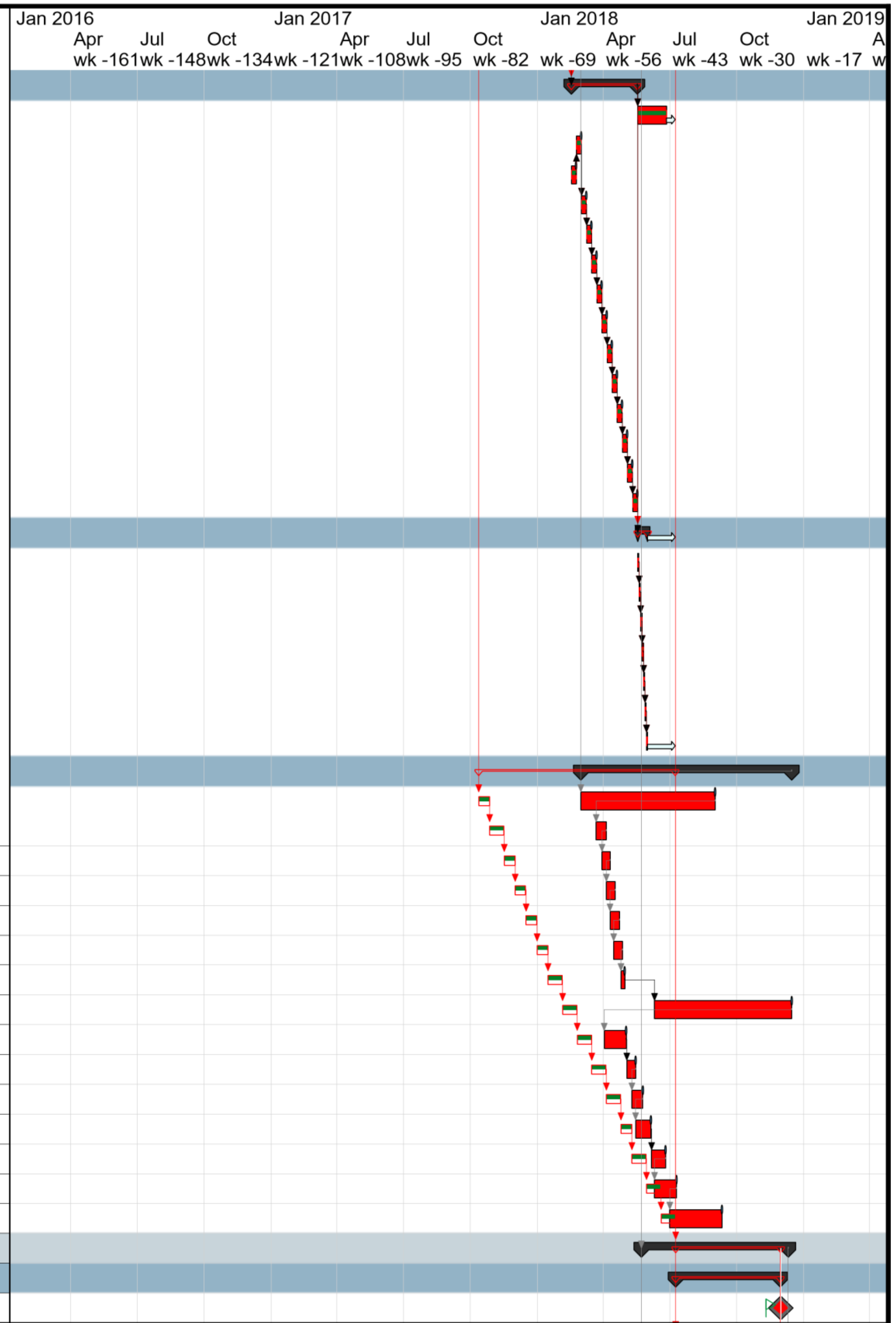
	ID	Name	Duration	BL Early Finish	BL Early Start	Actual Start	Actual Finish	Resources Code (Text1)
44	**3.2.00**	**3.b- Scavi per la realizzazione del Baiamonti, collettore acque di pioggia, impianti**	**91d**	**17:00 17/5/2018**	**08:00 16/2/2018**	**08:00 16/2/2018**	**17:00 17/5/2018**	
43	3.1.00	3.a - Scavi e riempimenti a 2+50 msm	40d	17:00 26/6/2018	08:00 18/5/2018	08:00 18/5/2018	17:00 26/6/2018	
46	3.2.02	Terreno 00	7d	17:00 1/3/2018	08:00 23/2/2018	08:00 23/2/2018	17:00 1/3/2018	T.00
45	3.2.01	Terreno 01	7d	17:00 22/2/2018	08:00 16/2/2018	08:00 16/2/2018	17:00 22/2/2018	T.01
47	3.2.03	Terreno 02	7d	17:00 8/3/2018	08:00 2/3/2018	08:00 2/3/2018	17:00 8/3/2018	T.02
48	3.2.04	Terreno 03	7d	17:00 15/3/2018	08:00 9/3/2018	08:00 9/3/2018	17:00 15/3/2018	T.03
49	3.2.05	Terreno 04	7d	17:00 22/3/2018	08:00 16/3/2018	08:00 16/3/2018	17:00 22/3/2018	T.04
50	3.2.06	Terreno 05	7d	17:00 29/3/2018	08:00 23/3/2018	08:00 23/3/2018	17:00 29/3/2018	T.05
51	3.2.07	Terreno 06	7d	17:00 5/4/2018	08:00 30/3/2018	08:00 30/3/2018	17:00 5/4/2018	T.06
52	3.2.08	Terreno 07	7d	17:00 12/4/2018	08:00 6/4/2018	08:00 6/4/2018	17:00 12/4/2018	T.07
53	3.2.09	Terreno 08	7d	17:00 19/4/2018	08:00 13/4/2018	08:00 13/4/2018	17:00 19/4/2018	T.08
54	3.2.10	Terreno 09	7d	17:00 26/4/2018	08:00 20/4/2018	08:00 20/4/2018	17:00 26/4/2018	T.09
55	3.2.11	Terreno 10	7d	17:00 3/5/2018	08:00 27/4/2018	08:00 27/4/2018	17:00 3/5/2018	T.10
56	3.2.12	Terreno 11	7d	17:00 10/5/2018	08:00 4/5/2018	08:00 4/5/2018	17:00 10/5/2018	T.11
57	3.2.13	Terreno 12	7d	17:00 17/5/2018	08:00 11/5/2018	08:00 11/5/2018	17:00 17/5/2018	T.12
58	**3.3.00**	**3.c - Realizzazione diaframma plastico con tecnica csm e sistema di drenaggio acque di fa**	**14d**	**17:00 31/5/2018**	**08:00 18/5/2018**	**08:00 18/5/2018**	**17:00 31/5/2018**	
59	3.3.01	Sottocordolo 00-09	2d	17:00 19/5/2018	08:00 18/5/2018	08:00 18/5/2018	17:00 19/5/2018	SC.0
60	3.3.02	Sottocordolo 10-19	2d	17:00 21/5/2018	08:00 20/5/2018	08:00 20/5/2018	17:00 21/5/2018	SC.1
61	3.3.03	Sottocordolo 20-29	2d	17:00 23/5/2018	08:00 22/5/2018	08:00 22/5/2018	17:00 23/5/2018	SC.2
62	3.3.04	Sottocordolo 30-39	2d	17:00 25/5/2018	08:00 24/5/2018	08:00 24/5/2018	17:00 25/5/2018	SC.3
63	3.3.05	Sottocordolo 40-49	2d	17:00 27/5/2018	08:00 26/5/2018	08:00 26/5/2018	17:00 27/5/2018	SC.4
64	3.3.06	Sottocordolo 50-59	2d	17:00 29/5/2018	08:00 28/5/2018	08:00 28/5/2018	17:00 29/5/2018	SC.5
65	3.3.07	Sottocordolo 60-69	2d	17:00 31/5/2018	08:00 30/5/2018	08:00 30/5/2018	17:00 31/5/2018	SC.6
66	**3.4.00**	**3.d - Pali di fondazione ed elevazione impalcato**	**289d, 1m**	**17:00 8/7/2018**	**08:00 12/10/2017**	**08:00 1/3/2018**	**08:01 15/12/2018**	
67	3.4.01	Impalcato 31	184d, 1m	17:00 26/10/2017	08:00 12/10/2017	08:00 1/3/2018	08:01 1/9/2018	IM.31
68	3.4.02	Impalcato 32	14d, 1m	17:00 15/11/2017	08:00 27/10/2017	08:00 22/3/2018	08:01 5/4/2018	IM.32
69	3.4.03	Impalcato 33	11d, 1m	17:00 30/11/2017	08:00 16/11/2017	08:00 30/3/2018	08:01 10/4/2018	IM.33
70	3.4.04	Impalcato 34	12d, 1m	17:00 15/12/2017	08:00 1/12/2017	08:00 5/4/2018	08:01 17/4/2018	IM.34
71	3.4.05	Impalcato 35	13d, 1m	17:00 30/12/2017	08:00 16/12/2017	08:00 10/4/2018	08:01 23/4/2018	IM.35
72	3.4.06	Impalcato 36	12d, 1m	17:00 14/1/2018	08:00 31/12/2017	08:00 15/4/2018	08:01 27/4/2018	IM.36
73	3.4.07	Impalcato 37	5d, 1m	17:00 3/2/2018	08:00 15/1/2018	08:00 25/4/2018	08:01 30/4/2018	IM.37
74	3.4.08	Impalcato 38	188d, 1m	17:00 23/2/2018	08:00 4/2/2018	08:00 10/6/2018	08:01 15/12/2018	IM.38
75	3.4.09	Impalcato 39	30d, 1m	17:00 15/3/2018	08:00 24/2/2018	08:00 2/4/2018	08:01 2/5/2018	IM.39
76	3.4.10	Impalcato 40	12d, 1m	17:00 4/4/2018	08:00 16/3/2018	08:00 3/5/2018	08:01 15/5/2018	IM.40
77	3.4.11	Impalcato 41	15d, 1m	17:00 24/4/2018	08:00 5/4/2018	08:00 10/5/2018	08:01 25/5/2018	IM.41
78	3.4.12	Impalcato 42	21d, 1m	17:00 9/5/2018	08:00 25/4/2018	08:00 15/5/2018	08:01 5/6/2018	IM.42
79	3.4.13	Impalcato 43	19d, 1m	17:00 29/5/2018	08:00 10/5/2018	08:00 6/6/2018	08:01 25/6/2018	IM.43
80	3.4.14	Impalcato 44	30d, 1m	17:00 18/6/2018	08:00 30/5/2018	08:00 10/6/2018	08:01 10/7/2018	IM.44
81	3.4.15	Impalcato 45	72d	17:00 8/7/2018	08:00 19/6/2018	08:00 1/7/2018	17:00 10/9/2018	IM.45
82	**4.0.00**	**4 -**	**202d**	**08:00 30/11/2018**	**08:00 9/7/2018**	**08:00 23/5/2018**	**17:00 10/12/2018**	
93	**4.2.00**	**4.d - Impianti**	**144d**	**17:00 29/11/2018**	**08:00 9/7/2018**	**08:00 9/7/2018**	**17:00 29/11/2018**	
107	0.0.02	Vincolo erogazione dei contributi europei	0d		08:00 30/11/2018	08:00 30/11/2018		



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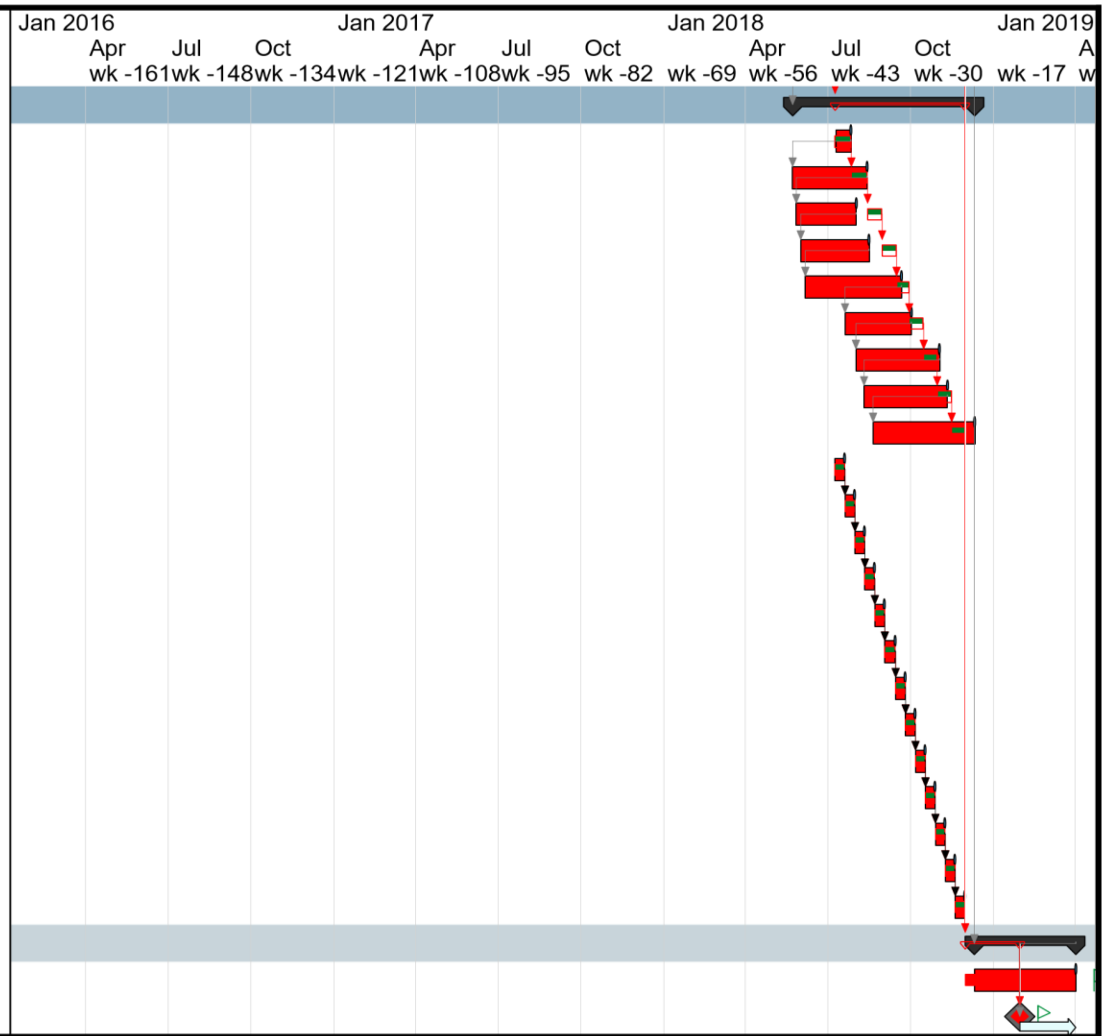
	ID	Name	Duration	BL Early Finish	BL Early Start	Actual Start	Actual Finish	Resources Code (Text1)
83	**4.1.00**	**4.a - Pali di fondazione ed elevazione impalcato**	**202d**	**17:00 29/11/2018**	**08:00 9/7/2018**	**08:00 23/5/2018**	**17:00 10/12/2018**	
84	4.1.01	Impalcato 46	17d	17:00 26/7/2018	08:00 9/7/2018	08:00 10/7/2018	17:00 26/7/2018	IM.46
85	4.1.02	Impalcato 47	83d	17:00 13/8/2018	08:00 27/7/2018	08:00 23/5/2018	17:00 13/8/2018	IM.47
86	4.1.03	Impalcato 48	67d	17:00 29/8/2018	08:00 14/8/2018	08:00 27/5/2018	17:00 1/8/2018	IM.48
87	4.1.04	Impalcato 49	76d	17:00 14/9/2018	08:00 30/8/2018	08:00 1/6/2018	17:00 15/8/2018	IM.49
88	4.1.05	Impalcato 50	107d	17:00 28/9/2018	08:00 15/9/2018	08:00 6/6/2018	17:00 20/9/2018	IM.50
89	4.1.06	Impalcato 51	74d	17:00 14/10/2018	08:00 29/9/2018	08:00 20/7/2018	17:00 1/10/2018	IM.51
90	4.1.07	Impalcato 52	93d	17:00 29/10/2018	08:00 15/10/2018	08:00 1/8/2018	17:00 1/11/2018	IM.52
91	4.1.08	Impalcato 53	93d	17:00 14/11/2018	08:00 30/10/2018	08:00 10/8/2018	17:00 10/11/2018	IM.53
92	4.1.09	Impalcato 54	113d	17:00 29/11/2018	08:00 15/11/2018	08:00 20/8/2018	17:00 10/12/2018	IM.54
94	4.2.01	Cordolo 00-05	11d	17:00 19/7/2018	08:00 9/7/2018	08:00 9/7/2018	17:00 19/7/2018	CO.00-05
95	4.2.02	Cordolo 06-10	11d	17:00 30/7/2018	08:00 20/7/2018	08:00 20/7/2018	17:00 30/7/2018	CO.06-10
96	4.2.03	Cordolo 11-15	11d	17:00 10/8/2018	08:00 31/7/2018	08:00 31/7/2018	17:00 10/8/2018	CO.11-15
97	4.2.04	Cordolo 16-20	11d	17:00 21/8/2018	08:00 11/8/2018	08:00 11/8/2018	17:00 21/8/2018	CO.16-20
98	4.2.05	Cordolo 21-25	11d	17:00 1/9/2018	08:00 22/8/2018	08:00 22/8/2018	17:00 1/9/2018	CO.21-25
99	4.2.06	Cordolo 26-30	12d	17:00 13/9/2018	08:00 2/9/2018	08:00 2/9/2018	17:00 13/9/2018	CO.26-30
100	4.2.07	Cordolo 31-35	11d	17:00 24/9/2018	08:00 14/9/2018	08:00 14/9/2018	17:00 24/9/2018	CO.31-35
101	4.2.08	Cordolo 36-40	11d	17:00 5/10/2018	08:00 25/9/2018	08:00 25/9/2018	17:00 5/10/2018	CO.36-40
102	4.2.09	Cordolo 41-45	11d	17:00 16/10/2018	08:00 6/10/2018	08:00 6/10/2018	17:00 16/10/2018	CO.41-45
103	4.2.10	Cordolo 46-50	11d	17:00 27/10/2018	08:00 17/10/2018	08:00 17/10/2018	17:00 27/10/2018	CO.46-50
104	4.2.11	Cordolo 51-55	11d	17:00 7/11/2018	08:00 28/10/2018	08:00 28/10/2018	17:00 7/11/2018	CO.51-55
105	4.2.12	Cordolo 56-60	11d	17:00 18/11/2018	08:00 8/11/2018	08:00 8/11/2018	17:00 18/11/2018	CO.56-60
106	4.2.13	Cordolo 61-65	11d	17:00 29/11/2018	08:00 19/11/2018	08:00 19/11/2018	17:00 29/11/2018	CO.61-65
108	**5.0.00**	**5 - Pavimentazione a terra, arredi di banchina**	**113d**	**17:00 29/1/2019**	**08:00 30/11/2018**	**08:00 10/12/2018**	**17:00 1/4/2019**	
109	5.1.01	Ro-Ro	113d	17:00 29/1/2019	08:00 30/11/2018	08:00 10/12/2018	17:00 1/4/2019	RR
110	0.0.03	Fine	0d	17:00 29/1/2019				



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